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POUR L'EXPLORATION DE LA MER
CHARLOTTENLUND SLOT – DANEMARK

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VOL. XIV · NO. 1

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E. S. RUSSELL

EN COMMISSION CHEZ
ANDR. FRED. HØST & FILS
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AVRIL 1939

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S. A. R. Valdemar, Prince de Danemark,
1858—1939.

SON Altesse Royale le Prince Valdemar de Danemark, est né le 27 octobre 1858, et mourut le 14 janvier 1939. Se déstinant à la carrière d'officier de marine, le Prince passa par tous les grades et participa à de nombreuses croisières. Parmi celles-ci, il faut signaler l'expédition de la "Valkyrie" dans les mers de l'Extrême Orient (1899—1900).

Il manifesta un vif intérêt pour les explorations de la mer, et contribua au prestige en patronnant plusieures expéditions organisées au Danemark sous la direction du professeur Johannes Schmidt. Citons: les deux expéditions de

la goëlette à moteur "Dana I", appartenant à "Østasiatisk Kompagni" 1920 et 1921. A cette époque les recherches scientifiques se concentraient plus spécialement dans la Mer des Sargasses, en vue d'étudier les conditions de la fraieson des anguilles.

Le prince prit un intérêt tout particulier à l'expédition Atlantique du navire "Dana II", équipé spécialement pour des recherches océanographiques, du $^{30}/_{8}$ 1921 au $^{11}/_{7}$ 1922 ainsi qu'à l'expédition autour du monde, du $^{14}/_{6}$ 1928 au $^{30}/_{6}$ 1930 subventionnée par la Fondation Carlsberg. Lors du retour de ces expéditions, en 1922 et en 1930, le Prince Valdemar, en compagnie de son neveu et ami intime, Son Altesse Royale le Prince Georges de Danemark et de Grèce, se rendit à Elseneur pour leur souhaiter la bienvenue. De temps en temps, les deux princes venaient visiter les collections "Dana", d'abord au laboratoire de Carlsberg, plus tard au palais de Charlottenlund, et les membres du Conseil international pour l'Exploration de la Mer, ainsi que les experts qui les assistent, ont souvent eu le plaisir de les rencontrer dans la maison hospitalière de Madame Ingeborg Schmidt.

Les nombreux témoignages de condoléance envoyés par des biologues et des océanographes à la famille royale à l'occasion de la mort du Prince Valdemar, disent assez combien son Altesse Royale sera regrettée dans ce cercle de chercheurs.

Martin Knudsen.

John Oliver Borley.

1872—1938.

THE death of John Oliver Borley has deprived the science of marine biology of one of its stalwarts and the International Council for the Exploration of the Sea of a trusty colleague and a faithful, well-loved friend.

The International Council stands, above all, for loyal, friendly, and honest co-operation in research. Borley was a type of the Council's ideal. He set us all a magnificent example. Nowhere could one have found a better team worker, for he was endowed with the team spirit. Always, in Borley's life and work, the work came first, himself last. Self-seeking was entirely foreign to his character: caution

and truth were his guiding principles; he never aimed at anything sensational.

In recent years we, of the International Council, have, perhaps, come to think of Borley chiefly as an expert of the Whaling Committee. His work with the Discovery Committee in England and with the Whaling Committee of the Council, and his grasp of the essentials of the whaling situation, coupled with his capacity for lucid and restrained exposition of facts, had much to do with the attainment of international agreements for the preservation of the stock of whales. But the value of his contribution to the discussion of whaling problems sprang from his long experience of fishery research. He served a long apprenticeship in that field of study and became a master of its technique. He was one of the pioneers of fishery research, as we understand the word to-day. He was one of those who laid the foundations of our technique. From 1903, when the International Council was in its infancy, to 1928, when he left the English Ministry of Agriculture and Fisheries to join the Colonial Office and devote his attention principally to whaling matters, he worked faithfully and constructively in the service of the fisheries, except for the period of the Great War, which involved the suspension of the English research work. During this period Borley worked with the same self-effacing zeal at other necessary tasks and his service was rewarded with the Order of the British Empire.

In the field of fisheries his name will always be associated with his investigations of the plaice fisheries. Nobody, I think, had a more complete mastery of the life history of the plaice and of the problems of the conservation of the stock of plaice. On this subject he spoke with unrivalled authority, solidly founded on hard and steadfast work, enthusiasm tempered by common sense and devotion to truth, and shrewd perspicacity. Borley's work on the plaice fisheries set a standard which any worker in marine biology may well be proud to emulate. It was an illuminating object lesson in the study of the whole problem of over-fishing. It was a first, invaluable step towards the results which have since been achieved in dealing, albeit tentatively and timidly, with this problem by international agreement. His reputation will, I think, wax rather than wane with the passage of time. We, of his generation, will not forget his service to the cause which is our special concern. Still less shall we forget the loyalty, sincerity, and truth, which endeared him to us all.

H. G. M.

Das Plankton der Ostsee vor der ostpreussischen Küste.

Von

H. Schmidt-Ries,
Institut für Schädlingsforschung,
Rossitten, Kuhr. Nehrung.

VOM Plankton der Ostsee geben verschiedene, grössere Arbeiten Kenntnis (Apstein, 1901; Driver, 1906; Merkle, 1910; Mielck, 1928; Lakowitz, 1919; Rapeport, 1929; Berzins, 1932; Mielck und Künne, 1935). Eine eingehendere Berücksichtigung fand das Plankton vor der ostpreussischen Küste jedoch bisher nur durch die Veröffentlichung eines Planktonkalenders von Sommer (1936). Aber auch diese Arbeit will keinen Anspruch auf eine möglichst umfassende Darstellung aller Plankter erheben. Bevor nun mit der Bearbeitung des Planktons vor der ostpreussischen Küste auf Grund quantitativer Bewertungen begonnen wird, will ich einige Bemerkungen darüber machen, welche Methode nach meinen Erfahrungen hierfür geeignet ist, mit welchen Planktern man rechnen muss, wo und wann diese im Untersuchungsgebiet auftreten.

Die Methodik.

Auswahl der geeigneten Methodik.

Zur Gewinnung und quantitativen Bewertung kleinerer Plankter, des sogenannten "Nannoplanktons" kommen die Zentrifugenmethode oder eine Kammermethode in Frage. Die Leistungsfähigkeit der Zentrifugenmethode (Lohmann) wurde bereits von mir geprüft und dabei festgestellt, dass sie bei der Bewertung von Süsswasserplanktern unzuverlässige Werte ergibt, deren Zufälligkeit noch durch Teilzählung

des Sedimentes gesteigert werden kann (Schmidt-Ries, 1936). Diese Prüfung war selbstverständlich nur für eine Entscheidung darüber gedacht, ob die Zentrifugenmethode fernerhin zur Gewinnung biologischer, quantitativer Werte bei limnologischen Untersuchungen Verwendung finden sollte. Während ihrer Durchführung berücksichtigte ich deshalb auch die Ergebnisse ozeanographischer, methodischer Untersuchungen (von Lohmann, Wulff, Steemann Nielsen) nur, soweit es notwendig erschien. Hypothetische Versuche einer rein theoretischen Beweisführung für die Leistungsfähigkeit der Zentrifugenmethode wie die von Hentschel (1932—1936) hielt ich nicht für so wichtig, um über ihre Stichhaltigkeit zu streiten. Dass ich derartige Einwände nicht übersehen habe, wie mir Hentschel (1936) vorwirft, widerlegt einmal meine Feststellung (S. 580—581), dass die Teilzählungsmethode des Zentrifugates von Hentschel im Gegensatz zu der von Lohmann willkürlich und unkontrollierbar ist, da sie eine unendliche Reihe von Möglichkeiten bietet, dann aber auch mein Literaturverzeichnis. Ich halte es aber auch heute für zwecklos, sich mit den erneut von Hentschel (1936) aufgestellten Behauptungen auseinanderzusetzen. Behauptungen können eben nur durch praktische Beweise gesichert werden, niemals aber durch weitere Behauptungen. Derartige experimentelle Beweise für die Leistungsfähigkeit der Methode und die Richtigkeit der Einwendungen hat aber Hentschel noch nicht erbracht. Wenn ich überhaupt an dieser Stelle auf seine Ausführungen (Hentschel, 1936) eingehe, geschieht es, um folgendes richtigzustellen: Hentschel (1936) will den Eindruck erwecken, dass ich Kritik an den Methoden und Ergebnissen der "Meteor" Expedition üben wollte, was vollkommen irreführend ist. Tatsächlich habe ich ausser im Literaturverzeichnis mit keinem Wort die Expedition erwähnt, lag es doch garnicht im Rahmen meiner Aufgabe, sie zu berücksichtigen. Selbstverständlich halte ich es auch ferner nicht für meine Aufgabe, ihre Ergebnisse anzuzweifeln oder nachzuprüfen und den Anhängern der Zentrifugenmethodik ihre methodische Beweisführung zu ersparen.

Spielt die Zentrifugenmethode bei limnologischen Untersuchungen gegenüber den Kammermethoden (Kolkwitz, Utermöhl) bereits seit Jahren keine Rolle mehr, tritt sie nunmehr nach den Feststellungen von Steemann Nielsen, Wattenberg und Meyer u.a. auch bei ozeanographischen Untersuchungen vollkommen in den Hintergrund. Da auch Hentschel (1936) angibt, seit 1932 nicht mehr mit ihr gearbeitet zu haben, bleibt ihr nur noch historischer Wert. Ihre Verwendungsmöglichkeit bei chemischen Bestimmungen bleibt davon unberührt (Steemann Nielsen und v. Brand, 1934).

Konnte ich bereits bei Planktonuntersuchungen in den ostpreussischen Haffen feststellen, dass für quantitative, biologische Bestimmungen nur die Kammermethoden, insbesondere die Röhrenkammermethode (Utermöhl) in Frage kommt (Schmidt-Ries, 1939), so erwies sich bei Untersuchungen vor der ostpreussischen Küste diese Methode ebenfalls als die geeigneteste. Zwei Gründe waren ausschlaggebend:

Einmal machte die hohe Triptonmenge die Verwendung jeder anderen Methode unmöglich, dann aber verlangten die starken Schwankungen der Individuenmengen der Plankter eine Methode, deren Fehler bestimmbar und korrektionsfähig ist. Bei Untersuchungen über die Planktonverteilung auf der Hochsee mag es angehen, Individuenmengenschwankungen von 100, ja 1000 Einheiten als unwesentlich anzusehen und mit einer Methode zu arbeiten, deren Fehlergrenze ebenfalls so gross ist oder vielleicht garnicht bestimmbar ist, bei Untersuchungen im Süsswasser, und Brackwasser, einschliesslich der Küstenzonen ist dieses nicht zulässig. Hier ist es von Wichtigkeit zu wissen, ob u.U. 10 oder 20 Individuen mehr oder weniger vorhanden sind, wenn entschieden werden soll, welche Planktonschichtung vorhanden ist. Auch mathematische Berechnungen spielen keineswegs eine überflüssige Rolle, so kann häufig nur mit der Fehlerberechnung entschieden werden, ob die Werte für zwei Meterproben identisch sind oder nicht. Derartige Berechnungen sind aber nur möglich, wenn die quantitative Methode es gestattet, Mittelwerte und mittlere Fehler zu bestimmen. Dieses ist aber nur mit Kammermethoden möglich. Auch vor der ostpreussischen Küste, wo sich die verschiedenen Wasserkörper aus den Haffen, den Bächen der Samlandküste und von der Hochsee mit ihren verschiedenartigen Bewohnern schichten und mischen, sind derartige genaue Bestimmungen nicht zu umgehen.

Nun kommt es aber nicht allein darauf an, eine gewisse Planktongruppe zu bewerten, sondern das "gesamte Plankton". Bisher ist es noch keineswegs bewiesen, dass Planktongruppen, die entweder durch die Fehler der Methodik ± zufallsbedingt zusammengesetzt sind, z.B. das sogenannte Netz-, Pumpen-, Zentrifugenplankton, oder die rein subjektiv nach ihrer Grösse vom Untersucher eingeordnet worden sind, z.B. Macro-, Micro-, Nannoplankton, als Repräsentanten des Gesamtplanktons gelten können.

Es hat im Gegenteil S t e e m a n n N i e l s e n (1938) gezeigt, dass das Phytoplankton, das mit Hilfe eines Planktonnetzes gewonnen wurde, nicht nur mengenmässig hinter jenem zurückbleibt, dass mit dem Wasserschöpfer gewonnen und mit Röhrenkammern ausgezählt wird, sondern auch eine Anzahl Formen überhaupt nicht und die übrigen nicht einmal im richtigen Verhältnis ihrer Häufigkeit zu einander erfasst werden. Die Zusammensetzung der methodisch bedingten Planktongruppe ist demnach rein zufällig, und die Planktongruppe ist keineswegs ein scharf umgrenzter und natürlicher Teil des Gesamtplanktons. Was für das Netzplankton gilt, gilt nach meinen Feststellungen auch für das Zentrifugen- und Pumpenplankton.

Ebensowenig berechtigt ist es auch, eine Planktongruppe, die nach rein subjektiven Gesichtspunkten umgrenzt wurde, als Repräsentant des Gesamtplanktons betrachten zu wollen, werden doch u.U. nicht einmal die Entwicklungsstadien einer einzigen Planktonform innerhalb einer Grössengruppe erfasst. Niemand, der mit der Röhrenkammermethode arbeitet, wird auf den Gedanken kommen, die Plankter, die er z.B. in einer 20 c.c. Kammer ohne Schwierigkeit mit einer bestimmten optischen

Vergrösserung zählen kann, und die ebenfalls eine Planktongrössengruppe darstellen, als Repräsentanten des Gesamtplanktons ansehen zu wollen. Wer seine Röhrenkammerserie von ½ bis 100 c.c. mustert, muss zu der gleichen Erkenntnis wie Steemann Nielsen (1938) kommen, dass es kein "Microplankton" und kein "Nannoplankton", sondern nur ein Phytoplankton gibt. Weitere Unterteilungen als die von Phytoplankton, Zooplankton und Ultraplankton oder Produzenten, Konsumenten und Reduzenten sind unnatürlich und vollständig überflüssig.

Die Röhrenkammermethode (Utermöhl) als Universalmethode gestattet die Bewertung des Gesamtplanktons in der Art, dass alle vorkommenden Plankter einzeln nach ihrer absoluten Häufigkeit zahlenmässig gewertet werden können. Dieses im vollen Umfange durchzuführen ist u.U. einem einzigen Untersucher aus Zeitmangel nicht möglich. Falls er sich nicht auf die Berücksichtigung der natürlichen Planktongruppen, des Zooplanktons oder des Phytoplanktons oder des Ultraplanktons beschränkt, wird er zur Kennzeichnung der Gesamtproduktion usw. Planktonformen aller Grössen aussuchen, die entweder durch ihre Häufigkeit oder auch ihre Seltenheit als Leitformen dienen.

Wenn Plankter berücksichtigt werden, deren Individuenmengen in den geschöpften Wasserproben noch nicht quantitativ verwertbar sind, ist es notwendig, eine grössere Wassermenge zu untersuchen. Da es nun kaum möglich ist, diese bis zum Laboratorium *in toto* zu transportieren, oder ihre Aufbewahrung einen zu grossen Raum beansprucht, muss die Wassermenge eingeengt werden. Durch das Dazwischenschalten eines Filters kann nun eine unkontrollierbare Fehlerquelle geschaffen werden. Dieses tritt jedoch nur ein, wenn ein Filter benutzt wird, dessen filtrierende Fläche horizontal gelagert ist und leicht mit Luft in Berührung kommt, wie z.B. das von Hentschel (1938) benutzte Filter. Benutzt man jedoch ein Kolkwitzsieb, dessen filtrierende Flächen senkrecht stehen und stellt es in einen Wasserbehälter (Utermöhl, 1930), der mit Wasser gefüllt ist, so wird sowohl die Zerstörung der Plankter vermieden, als auch diese durch die drucklose Filtrierung nicht durch die Filtermaschen gedrückt. Die Brauchbarkeit eines Filters zeigt sich am besten im Winter bei niederen Temperaturen. Ein horizontal gelagertes Filter ist sofort vereist und unbrauchbar, auch ein Kolkwitzsieb vereist sofort, wenn es aus dem Wasser gehoben wird und ist nur mit Mühe wieder aufzutauen. In solchen Fällen lasse ich das Sieb in dem Wasserbehälter, setze KJ+J zur Fixierung zu, warte, bis sich die Plankter abgesetzt haben und hebere das Sediment ab. Die dazu benutzten Pipetten bewahre ich in Spiritus auf. Die Zooplankter und Phytoplankter, bei denen wegen ihrer Kleinheit die Gefahr besteht, dass sie die Siebmaschen passieren, können, falls sie überhaupt produktionsbiologisch wichtig sind, auch mit Hilfe von 50 und 100 c.c.-Kammern ausgezählt werden. Auf diese Weise ist sogar eine Kontrolle möglich, welche Formen durch die Siebmaschen gehen. Eine quantitative Bestimmung aber ist in jedem Falle möglich.

Durchführung der Untersuchungen.

Ob nun die Planktonproduktion als solche oder die Verteilung von Wasserkörpern mit Hilfe quantitativer Planktonbestimmungen vor der ostpreussischen Küste festgestellt werden soll, eine eingehende Berücksichtigung der gesamten Wassersäule auf jeder Untersuchungsstation ist notwendig. Die Untersuchung von Oberflächenfängen allein genügt nicht, worauf auch Steemann Nielsen (1938) hinweist. Da in jedem Falle die Kenntnis der vertikalen Planktonverteilung von Wert ist, sind mit dem Wasserschöpfer in einzelnen Wassertiefen Stichproben zu entnehmen. In welchem Meterabstande dieses zu erfolgen hat, kann bei geeignetem Fahrzeug während der Probeentnahme entschieden werden. Eine stärkere Jodkonzentration der KJ+J Lösung beschleunigt die Planktonsedimentation und gestattet bei einiger Übung durch Musterung von Zählstreifen sofort abzuschätzen, ob sich die Formenzusammensetzung oder auch die Individuenmenge der einzelnen Formen verändert, also eine quantitativ genaue Bestimmung angebracht ist. Ebensowenig wie es sich in jedem Falle als unbedingt notwendig erweist, den Gesamtplanktongehalt zu bestimmen, ist es auch notwendig, den Gesamtplanktongehalt einer Wassersäule zu bestimmen. Falls allerdings die horizontale Verbreitung genau bestimmt werden soll, ist es notwendig, einen Wert für jede Planktonform auf jeder einzelnen Station zu erhalten. Dieses muss ein Mittelwert mit einem mittleren Fehler sein, um Individuenunterschiede berechnen zu können. Je weniger die Planktonschichtung in den einzelnen Metern schwankt, und mit wachsender Wassertiefe eine Planktonansammlung dicht über dem Boden seltener wird, desto genauer kann der Wert werden. Wo sich verschiedene Wasserkörper schichten, kann natürlich nicht ein Gesamtwert für eine Wassersäule berechnet werden, sondern müssen mehrere Werte bestimmt werden.

Derartige quantitative Methoden sind nicht notwendig, wenn lediglich die vorkommenden Plankter und ihr durchschnittliches Vorkommen im Untersuchungsgebiet festgestellt werden sollen. Um die grösseren Plankter zu erhalten, genügt ein Planktonnetz. Ausserdem sind aber stets Schöpffänge notwendig, möglichst mit einem Wasserschöpfer. Wie überhaupt die kleineren Plankter nur auf diese Weise gewonnen werden können.

Da mir für meine Untersuchungen nur meine Freizeit zur Verfügung stand, konnte ich keine quantitativen Untersuchungen durchführen, sondern arbeitete rein qualitativ sammelnd mit Netz und Schöpfgefässen[1]). Die Untersuchungen erstreckten sich vom Jahre 1932 bis Ende 1938. Die Proben stammten hauptsächlich aus den Küstenzonen von Pillau bis nach Memel innerhalb einer Zone von ca. 7 Sm. Ergänzen konnte ich diese noch durch Proben ausserhalb dieser Zone und aus den beiden ostpreussischen Haffen.

[1]) Herrn Prof. Dr. Willer, ehemaligem Direktor des Fischerei-Institutes, Königsberg i. Pr., danke ich für sein Interesse zu Beginn meiner Untersuchungen und gelegentlichen Überlassung eines Planktonnetzes und Wasserschöpfers.

Das Plankton.

Die vorkommenden Plankter.

Zooplankton.

1. *Cyphoderia calceolus* Pen.
2. *Stentor multiformis* (Müller).
3. *Strombidium stylifer* Lev.
4. *Urolepsis piscis* O. F. Müller
5. *Cothurnia maritima* Cohn
6. *Helicostomella subulata* Ehrenbg.
7. *Tintinnopsis beroidea* Entz.
8. *T. tubulosa* L.
9. *T. tubulosa* var. *subacuta* Jörgensen
10. *T. campanula* var. *cyathus* Dad.
11. *T. baltica* Br.
12. *T. lacustris* Entz.
13. *Tintinnidium fluviatile* Stein
14. *Leprotintinnus bottnicus* Jörgensen
15. *Lindia tecusa* Harring +Myers
16. *Synchaeta fennica* Rouss.
17. *S. baltica* Ehrbg.
18. *S. litoralis* Rouss.
19. *S. monopus* Plate
20. *Trichocerca marina* Daday
21. *Tr. capucina* Wierz.+ Zach.
22. *Pedalion oxyuris* Sernow
23. *Rotatoria rotatoria* Schr.
24. *Diurella stylata* Eyferth
25. *Brachionus urceus* L.
26. *Br. angularis* Gosse
27. *Br. angularis* var. *bidens* Plate
28. *Br. capsuliflorus* var. *cluniorbicularis* Pallas
29. *Euchlanis dilatata* (Ehrbg.)
30. *Keratella cruciformis* var. *eichwaldi* Levander
31. *K. stipitata* Ehrbg.
32. *Keratella quadrata* Müll.
33. *K. cochlearis* Gosse
34. *K. cochlearis* var. *tecta* Gosse
35. *Filinia longiseta* Ehrenbg.
36. *Notholca longispina* Kallicot
37. *N. acuminata* Ehrenbg.
38. *N. striata* Kallicot
39. *Colurella colurus* Ehrbg.
40. *Evadne nordmanni* Loven.
41. *Podon polyphemoides* Leukart
42. *P. intermedius* Lillj.
43. *Bosmina coregoni-maritima* Müll.
44. *Diaphanosoma brachyurum* var. *leuchtenbergianum* Fischer
45. *Chydorus sphaericus* O. F. Müller
46. *Centropages hamatus* Lillj.
47. *Acartia bifilosa* Giesl.
48. *Eurytemora hirundoides* Nordqvist
49. *Eu. hirundo* Giesl.
50. *Eu. affinis* Poppe
51. *Diaptomus graciloides* Lillj.
52. **Temora longicornis* Müll.
53. *Cyclops leuckarti* Claus
54. *C. serrulatus* Fischer
55. *C. viridis* Jurine
56. Nauplien von *Balanus improvisus* Darwin
57. Larven von *Dreissensia polymorpha* Pall.
58. Larven von *Mytilus edulis* L.
59. Larven von *Hydrobia spec.*
60. *Neomysis vulgaris* J. V. Tompson

Phytoplankton.

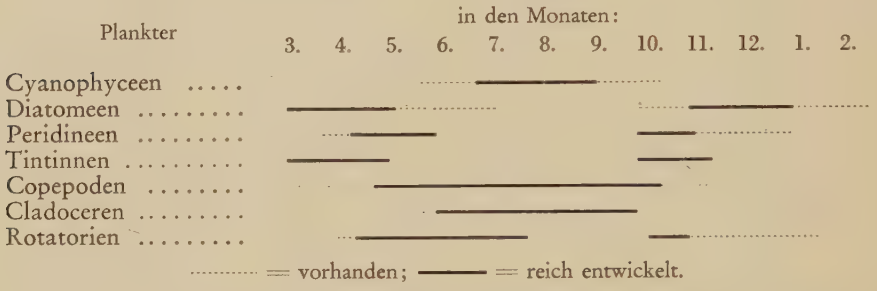
1. *Radiosperma corbiferum* Meunier
2. *Gonium sociale* Duj. Werm.
3. *Phacus longicuada* (Ehrbg.) Duj.
4. *Euglena oxyuris* Schmarda
5. *Peridinium pellucidum* (Bergh.) Schütt
6. *P. oblongum* Aurivillius
7. *Dissodinium lunula* (Schütt)
8. *Gonyaulax catenata* Kofoid
9. *G. triacantha* Jörg.
10. *Dinophysis ovum* var. *baltica* Pauls.
11. *D. acuminata* Claparède e. Lachm.
12. Gymnodinien spec. spec.
13. Glenodinien spec. spec.
14. *Melosira granulata status* γ Müller
15. *M. varians* Ag.
16. *M. islandica* subsp. *helvetica* v. Goor.

* *Paracalanus parvus* Claus und *Oithona similis* Claus sind äusserst selten.

17. *Melosira moniliformis* (Müll.) Agardh
18. *M. arctica* (Ehrbg.)
19. *M. jürgensi* Ag.
20. *Fragilaria crotonensis* Kitt.
21. *Fr. capucina* Desm.
22. *Asterionella formosa* Hassal
23. *Diatoma elongatum* Agardh
24. *D. vulgare* Bory
25. *Nitzschia acicularis* var. *closteroides* W. Smith
26. *Thallasiosira baltica* Ostenf.
27. *Th. decipiens* (Grun.) Jörgensen
28. *Coscinodiscus oculus iridis* Ehrenbg.
29. *C. radiatus* Ehrenbg.
30. *C. excentricus* Ehrenbg.
31. *C. excentricus* var. *fasciculata* Hustedt
32. *C. rothii* var. *subsalsa* Hustedt
33. *C. jonesianus* var. *commutata* Hustedt
34. *C. lacustris* Grunow
35. *Actinocyclus ehrenbergi* Ralfs
36. *A. ehrenbergi* var. *crassa* Hustedt.
37. *Rhizosolenia minima* Lev.
38. *Chaetoceros crinitus* Schütt.
39. *Ch. wighami* Brightwell
40. *Ch. danicus* Cleve
41. *Ch. borealis* Bailey
42. *Ch. brevis* Schütt
43. *Sceletonema costatum* (Grev.) Cleve
44. *Achnanthes taeniata* Grunow
45. *Navicula salinarum* Grun.
46. *Navicula peregrina* (Ehrbg.) Kütz.
47. *Amphora ovalis* Kütz.
48. *A. commutata* Grun.
49. *A. holsatica* Hust
50. *Rhoicosphenia curvata* (Kütz.) Grun.
51. *Surirella striatula* Turp.
52. *S. spiralis* Kütz.
53. *S. biseriata* var. *rostrata* Schulz
54. *Campylodiscus echeneis* Ehrenbg.
55. *C. clypeus* Ehrenbg.
56. *Pleurosigma elongatum* W. Smith
57. *Cymbella cistula* (Hemprich) Grun.
58. *Gyrosigma balticum* (Ehrbg.) Rabh.
59. *Gyrosigma strigile* W. Smith
60. *Pediastrum clathratrum* (Schöber) Lemmermann
61. *P. boryanum* var. *longicorne* Reinsch
62. *P. boryanum* var. *divergens* Lemm.
63. *P. duplex* var. *pulchrum* Lemm.
64. *P. kawraiskyi* Schmidle
65. *P. integrum* var. *braunianum* Nordst.
66. *Oocystis solitaria* Wittrock
67. *O. submarina* Lagerh.
68. *O. pelagica* Lemm.
69. *Ankistrodesmus falcatus* Ralfs
70. *Scenedesmus quadricauda* Breb.
71. *Sc. obliquus* Turp. Kütz.
72. *Coelastrum microporum* Näg.
73. *C. reticulatum* Lemm.
74. *Tetrastrum multisetum* (Schmidle) Chodat
75. *T. multisetum* var. *punctatum* Schmidle
76. *Tetraëdron cruciatum* f. *minor.* Turn.
77. *Crucigenia fenestrata* Schmidle
78. *C. tetrapedia* W. u. W.
79. *Dictiosphaerium pulchellum* Wood.
80. *Bohlinia echidnia* Lemm.
81. *Trochiscia clevei* Lemm.
82. *Botryococcus braunii* Kütz.
83. *Cladophora spec.*
84. *Enteromorpha spec.*
85. *Prasiola spec.* + Aplanosporen
86. *Aphanizomenon flos aquae* L.
87. *Microcystis aeruginosa* Kütz.
88. *M. viridis* Lemm.
89. *Gomphosphaeria lacustris* Chodat
90. *Coelosphaerium dubium* Naeg.
91. *C. kützingianum* Naeg.
92. *C. naegelianum* Unger
93. *Merismopedia glauca* Naeg.
94. *Nodularia spumigena* Mert. f. *genuina* und f. *litorea*
95. *Anabaena hassallii* Kütz. Wittr.
96. *A. spiroides* Klebahn
97. *A. baltica* Schmidt
98. *Lyngbya limnetica* Lemm.
99. *L. contorta* Lemm.
100. *L. aestuarii* (Mert.) Lübm.

Die jahreszeitliche Entwicklung.

Den von Sommer (1936) angegebenen Planktonkalender kann ich für die angegebenen Plankter bestätigen. Abgesehen von geringen Abweichungen in den einzelnen Jahren konnte ich in der Küstenzone folgende jahreszeitliche Entwicklung feststellen:



Wenn ich für die Aufstellung dieses Kalenders nur Planktongruppen verwerte, nicht Leitformen, geschieht es, weil die Vertreter dieser Gruppen in den verschiedenen Jahren nicht immer dieselben sind.

Die jahreszeitliche Entwicklung in der Hochsee unterscheidet sich von der vor der Küste insofern, als im Frühjahr durch die langsamere Erwärmung des Wassers die Diatomeenentwicklung, die oft ein ausgesprochen monotones Planktonbild verursacht, länger andauert, und die Cyanophyceenentwicklung im Herbst durch die langsamere Abkühlung später aufhört. Auch die Cladoceren treten in der Hochsee im Jahre später auf als in der Küstenzone. Offenbar findet hier eine Besiedlung von den Küstenzonen aus statt, da ich niemals Ephippien auf der Hochsee antraf. Das Auftreten der Copepoden, Rotatorien, Peridineen und Tintinnen in der Hochsee und vor der Küste erfolgt nahezu gleichzeitig. Am auffallendsten unterscheidet sich die Planktonentwicklung der Hochsee von der der Küstengewässer und Haffe dadurch, dass Desmidiaceen und Protococcalen nur vereinzelt auftreten oder ganz fehlen. Diese sind in den Haffen oft massenhaft entwickelt, treten vor der Küste auch nur dort massenhaft auf, wo Haffwasser sich befindet.

Ihre örtliche Entwicklung.

Durch die Strömungen gelangen Plankter von der Hochsee bis dicht an die Küste, so besonders bei dem Badeort Cranz an der Samlandküste. Sie werden auch aus der Danziger Bucht und den Haffen an der Küste entlang bis in die Hochsee verschleppt (s. Strommessungen von Brückmann, 1919). Bei Haffplanktern, die vor der ostpreussischen Küste auftreten, handelt es sich vor allem um solche, die aus dem Frischen Haffe stammen, da der Küstenstrom zumeist nach Nord-Osten fliesst. Die Wassermassen des Kurischen Haffes berühren kaum die ostpreussische Küste. Sie sind noch weit auf der Hochsee als ± geschlossener Wasserkörper festzustellen. Apstein (1901),

Driver (1906) und Merkle (1910) trafen dort eine reiche Entwicklung von *Aphanizomenon flos aquae, Pediastrum boryanum, Nodularia spumigena* und *Fragilaria crotonensis* an und führten deren Vorkommen mit Recht auf den Einfluss der Haffe zurück. Untersuchungen von Rapeport (1929) und Berzins (1932) vermehrten die Kenntnis derartiger Plankter.

Am stärksten wechselt das Planktonbild vor den Haffmündungen. Hier verursacht insbesondere der stark wechselnde Salzgehalt ein Absterben vieler Planktonformen.

Die hydrographischen Verhältnisse vor der ostpreussischen Küste verursachen durchaus keine einheitliche Planktonentwicklung, sondern eine Ausbildung von Zonen mit verschiedenartiger Planktonzusammensetzung und -entwicklung. Wenn ich hier bereits versuche, diese Zonen zu kennzeichnen, tue ich es nur, weil mir die Planktonentwicklung während mehrerer Jahre bekannt geworden ist. Zunächst möchte ich das häufigste Vorkommen einzelner Plankter angeben.

Zooplankton.

Mysidacea.

Neomysis vulgaris kommt vor der ganzen Küste vor, gelangt mit eingehendem Strom im Frischen Haff bis zum Kahlholzer Haken, im Kurischen Haff bis zum Schweinsrücken. Die Form bildet einen Hauptbestandteil der Dorschnahrung.

Lamellibranchia.

Die freischwimmenden Veligerlarven sind in den Haffen wie vor der Küste anzutreffen. Die Larven von *Mytilus edulis* kommen dicht an der Küste und in den Haffen bei eingehendem Strom vor. Sie sterben jedoch in den Haffen ab. Ebenso wie umgekehrt die Larven von *Dreissensia polymorpha* in der Ostsee absterben, falls sie aus den Haffen dorthin geschwemmt werden. Im Frischen Haff kommen beide in einer Mischzone gleichzeitig vor. Stets ist auch im Sommer die *Hydrobia*-Larve im Plankton vor der Küste und im Frischen Haff, ohne allerdings grössere Individuenmengen zu erreichen.

Cirripedia.

In der Zeit von Juni bis September treten vor der Küste die freischwimmenden Nauplien von *Balanus improvisus* auf. In den Haffen sterben sie bald ab. Vereinzelt konnte ich auch *Cypris*-Formen ausser vor der ostpreussischen Küste in den Tiefs der Haffe beobachten.

Copepoda.

Copepoden sind ausser im Januar und Februar stets in grösserer Individuenmenge im ganzen Gebiet vorhanden. Ihre stärkste Entwicklung ist im Juni bis Juli. *Centropages hamatus* hat seine Hauptentwicklung auf der Hochsee; in der Küstenzone kommt er nur vereinzelt vor ebenso wie *Acartia bifilosa* und *Eurytemora hirundoides*. *Temora longicornis* ist dagegen stärker in Küstennähe vertreten, wo

auch *Eurytemora hirundo* auftritt. Nur stellenweise massenhaft vorkommend ist *Eurytemora affinis* Leitform für das Mischungsgebiet von Haff- und Ostseewasser. Das Frische Haff besiedelt der Plankter auf weite Zonen, im Kurischen Haff dagegen konnte ich ihn nur zeitweise bei eingehendem Strom beobachten. Der häufigste Cyclopide vor der Küste, der auch vereinzelt in der Hochsee vorkommt und in den Haffen reiche Individuenmengen erreicht, ist *Cyclops leuckarti. Cyclops serrulatus* und *Cyclops viridis* gelangen aus den Haffen, insbesondere dem Kurischen Haffe in die Ostsee, wo sie aber bald verschwinden. Es ist aber dieses unter Umständen darauf zurückzuführen, dass *Cyclops serrulatus* nicht ausgesprochen planktisch lebt. *Diaptomus graciloides* konnte ich ebenfalls nur vor der Haffmündung (Kurisches Haff) beobachten.

Phyllopoda.

Im Juni tritt *Evadne nordmanni* im ganzen Gebiet auf. Auch in die Haffe dringt der Plankter zusammen mit *Podon polyphemoides* bei günstigen Strömungsverhältnissen ein. *Podon intermedius* bleibt streng auf die Hochsee beschränkt. Die stärkste Entwicklung hat *Bosmina coregoni-maritima.* Im Juni bis Juli bevölkert sie die Küstenzone, dringt in die Haffe ein und bildet die Hauptnahrung von Sprotten, Strömlingen, Stinten und Makrelen, deren Darminhalt nach meinen Untersuchungen dann nur aus Bosminen besteht. *Diaphanosoma brachyurum* var. *leuchtenbergianum* ist ein typischer Haffplankter. Er kommt in vereinzelten Individuen an der Küste und auf der Hochsee vor. *Chydorus sphaericus* ist dagegen nur vor der Küste vereinzelt anzutreffen. Im Kurischen Haff tritt er im Plankton massenhaft auf.

Rotatoria.

Auch von den Rotatorien kommen einige Formen im gesamten Untersuchungsgebiet, vom Haff bis zur Hochsee vor.

Arten, die im Winter gleich häufig in den Küstenzonen der Ostsee und den Haffen vorkommen, sind: *Notholca striata, Notholca acuminata* und *Colurella colurus.* Vereinzelt traf ich sie auch im Plankton der Hochsee an. Es sind Formen, die ihre Hauptentwicklung bei niederen Wassertemperaturen haben. Im Sommer treten sie in den Haffen nur selten auf und fehlen in der Ostsee vollständig. In den Haffen und vor der Küste treten auch gleichzeitig im Juni bis Juli *Keratella quadrata, Keratella cochlearis* + var. *tecta, Notholca longispina* und *Filinia longiseta* auf. Die Individuenmengen von *Keratella quadrata* vor der Küste fand ich oft höher als im Kurischen Haff. Im Hochseeplankton fehlten diese Rotatorien bis auf vereinzelte Funde.

Arten, die selten in der Küstenzone ausser den Mündungsgebieten der Haffe und in den Haffen selbst, wohl aber massenhaft in den Tiefs der Haffe vorkommen, sind: *Brachionus capsuliflorus* var. *cluniorbicularis, Keratella stipitata* und *Keratella cruciformis* var. *eichwaldi.* Ihre Hauptentwicklung finden sie im Frischen Haff, da hier eine ausgedehnte Mischungszone von Ostseewasser und Haffwasser vorhanden

ist. Im Kurischen Haff kommen sie nur gelegentlich vor. Sie fehlen in der Hochsee vollständig.

Arten, die in der Hochsee fehlen, vor der Küste nur selten auftreten, in den Tiefs der Haffe und den Haffen in grösserer Menge das Pelagial besiedeln, sind: *Euchlanis dilatata, Brachionus angularis* + var. *bidens, Brachionus urceus, Trichocerca capucina, Diurella stylata* und *Rotatoria rotatoria.* Sie kommen während der warmen Jahreszeit vor.

Arten, die massenhaft in der Küstenzone entwickelt sind, vereinzelt auf der Hochsee auftreten und bis in die Haffe gelangen, sind: *Synchaeta monopus, Synchaeta litoralis* und *Synchaeta baltica,* die ich vor allem im Juni bis Oktober beobachten konnte. Im Winter stellte ich *Pedalion oxyuris* als zu dieser Gruppe gehörend fest.

Arten, die massenhaft auf der Hochsee, an der Küste nur vereinzelt vorkommen und vor dem Haff bereits fehlen, sind: *Trichocerca marina, Synchaeta fennica* und *Lindia tecusa.*

Tintinnidae.

Die häufigste Form ist *Tintinnopsis beroidea,* die von der Hochsee bis in die Brackwasserzonen der Haffe im Frühjahr und Herbst vorkommt. Eine noch stärkere Entfaltung konnte ich fast in jedem Jahre im Herbst bei *Helicostomella subulata* beobachten. Sie kommt jedoch vor der Küste nur in Oberflächenwasserschichten vor. Ihre Varietät *kiliensis* beobachtete ich nicht. Die übrigen Formen sind weniger auffallend vorhanden. *Tintinnopsis tubulosa* kommt in Küstennähe vor, auf der Hochsee lebt ihre Varietät *subacuta* zusammen mit *Leprotintinnus bottnicus.* Vereinzelt tritt auch *Tintinnopsis baltica* auf, die der Süsswasserform *Tintinnopsis lacustris* ähnelt. *T. lacustris* fehlt bereits vor der Haffmündung. Aus dem Haff gelangt aber *Tintinnidium fluviatile* in die Ostsee, wo ich sie vor der Mündung des Kurischen Haffes beobachten konnte.

Ciliata.

In jeder Planktonprobe ist *Cothurnia maritima* anzutreffen, eine Form, die auf *Chaetoceros* sitzt. Im Frühjahr tritt oft in Massenentwicklung vor der Küste *Uroleptus piscis* auf. Bei Jod + Jodkalium-Fixierung der Planktonprobe ist die Form deutlich an den drei einzelnen Griffeln auf dem Frontalfeld zu erkennen. *Strombidium stylifer* tritt im Tief des Kurischen Haffes mit 80—90 μ grossen Exemplaren auf. Sie bevorzugt offenbar Zonen mit reichen organischen Umsetzungen, ist so auch in der Mündungszone der Deime und Memel während des ganzen Jahres entwickelt. Im Neukuhrener Hafen stellte ich noch *Stentor multiformis* fest.

Protozoa.

Cyphoderia calceolus kommt ausser im Kurischen Haff auch vereinzelt vor der Küste vor. Die Gehäuse sind häufig auch in der Hochsee anzutreffen.

Phytoplankton.

Flagellata.

Der einzige Flagellat ausser Dinoflagellaten, der im Plankton vor der Küste in weiter Verbreitung anzutreffen ist, ist *Radiosperma corbiferum. Gonium sociale* gelangt durch die Tiefs der Haffe in die Ostsee, ohne sich aber dort weiter zu entwickeln. In den Tiefs, vor den Haffmündungen und im Neukuhrener Hafen treten *Phacus longicauda* und *Euglena oxyuris* auf.

Die Dinoflagellaten bilden im Frühjahr und Herbst eine beträchtliche Planktonentwicklung. Von den Peridinidae gelangt *Peridinium pellucidum* im September und Oktober zusammen mit *Perid. oblongum* von der Hochsee bis in die Nähe der Küste. Im Frühjahr ist *Dissodinium lunula* und *Gonyaulax catenata* zu beobachten, im Winter *Gonyaulax triacantha.* Von den Dinophysidae traf ich *D. ovum* var. *baltica* im Frühjahr und im Oktober, *Dinophysis acuminata* nur im Winter vereinzelt auf der Hochsee und vor der Küste an. Die Gymnodinien und Glenodinien sind in manchen Jahren dicht vor der Küste im Spätwinter und Frühjahr massenhaft vertreten. Eine eingehende Bestimmung werde ich noch durchführen.

Bacillariaceae.

Ausser in den Monaten August und September bilden die Kieselalgen den grössten Anteil an der Planktonlebensgemeinschaft. Aus den Haffen gelangen *Melosira granulata status* γ, M. *varians* und *M. islandica* subsp. *helvetica* in die Ostsee. Ihr Massenvorkommen in den Haffen sorgt auch in der Ostsee für eine weite Verbreitung, ohne dass eine wesentliche Vermehrung stattzufinden braucht. Sicher findet eine Vermehrung bei *Fragilaria crotonensis* und *Asterionella formosa* statt, die ebenso wie in den Haffen auch in den Küstenzonen besonders im Frühjahr wuchern und bis in die Hochsee anzutreffen sind. Von den Formen, die ebenfalls in die Ostsee aus den Haffen gelangen, dort aber sich nicht weiter entwickeln, sind noch zu nennen: *Diatoma elongatum, Diatoma vulgare, Fragilaria capucina, Nitzschia acicularis* + var. *closteroides.*

Ausser diesen kommt noch eine Anzahl Kieselalgen vor, die in den Haffen vollständig fehlen oder nur vereinzelt dort durch Ostseewassereinbrüche vorkommen: *Melosira moniliformis* tritt überall an der Küste auf, sehr häufig z.B. im Neukuhrener Hafen. Auch *Melosira arctica* ist im Mai, *Melosira jürgensi* im Frühjahr und Herbst nicht zu übersehen. Fällt bereits die Gattung *Thalassiosira* im Frühjahr mit *Th. baltica* weniger mit *Th. decipiens* durch ihre Massenentfaltung auf, so wird sie noch durch die Gattung *Coscinodiscus* übertroffen. *Coscinodiscus oculus iridis* ist die häufigste Form, daneben *C. radiatus.* Kommen diese Formen vor allem auf der Hochsee vor, ist *C. excentricus* auch vor der Küste reich entwickelt. Die häufigste Form vor der Küste ist *C. rothii* var. *subsalsa,* die zusammen mit *C. jonesianus* var. *commutata* und der Litoralform *C. lacustris* Leitform für die

Brackwasserzonen der Haffe ist. *C. rothii* var. kommt noch weit in den Haffen lebend vor. *C. jonesianus* var. stirbt am ersten ab. Auf das Vorkommen von *C. lacustris* im Kurischen Haff haben bereits früher Willer (1931, 1933) und Pratje (1931) hingewiesen. Auch die Gattung *Actinocyclus* mit *A. ehrenbergi* und var. *crassa* wuchert im Herbst und Winter vor der Küste und auf der Hochsee. Geringere Individuenmengen erreichen die anderen Gattungen. *Rhizosolenia minima* ist im Frühjahr und Herbst zu beobachten. *Chaetoceros crinitus* und *Ch. wighami* sind die häufigsten *Chaetoceros*-Arten vor der Küste, *Ch. danicus, Ch. borealis* und *Ch. brevis* auf der Hochsee. *Sceletonema costatum* ist eine Frühjahrsform, die zusammen mit *Achnanthes taeniata, Navicula salinarum* und *Navicula peregrina* vor der Küste vorkommt, unter Umständen auch in das Frische Haff gelangt.

Ausser diesen treten noch vereinzelte Formen im Plankton auf, die entweder nur in sehr geringer Menge entwickelt sind oder als Boden- oder Litoralformen nur gelegentlich in das Pelagial verschleppt werden: Im Haff und vor der Küste treten auf: *Amphora ovalis, A. commutata, Diploneis didyma, Rhoicosphenia curvata, Surirella striatula, S. spiralis, Campylodiscus echeneis, C. clypeus, Surirella biseriata* var. *rostrata, Pleurosigma elongatum.* Nur vor der Küste fand ich: *Cymbella cistula, Gyrosigma balticum* und *G. strigile.*

Chlorophyceae.

Im Vergleich zu den Haffen ist die Anzahl der Chlorophyceen im Plankton der Ostsee verschwindend klein. Sie nimmt in Richtung zur Hochsee mit schwindendem Einfluss der Haffe ab. Eine Weiterentwicklung findet in der See offenbar nicht statt. Am häufigsten sind noch Pediastren anzutreffen, z. B. *Pediastrum clathratrum, P. boryanum* var. *longicorne* und var. *divergens, P. duplex* var. *pulchrum, P. kawraiskyi, P. integrum* var. *braunianum.* Zwischen den Aphanizomenonbündeln vor der Küste und auch vereinzelt auf der Hochsee traf ich *Oocystis solitaria, O. submarina, O. pelagica, Ankistrodesmus falcatus, Scenedesmus quadricauda, Coelastrum microporum, C. reticulatum, Tetrastrum multisetum* + var. *punctatum, Tetraedron cruciatum* f. *minor.* Dieses sind alles Plankter, die ich auch im Kurischen Haff in der Aphanizomenonwasserblüte beobachten konnte. Es ist demnach als sicher anzunehmen, dass ein Zusammenhang, der sich bis weit in die Hochsee erstreckt, zwischen der Entwicklung in den Haffen und der Ostsee dadurch besteht, dass einheitliche Wasserkörper aus den Haffen noch lange Zeit in der Ostsee bestehen bleiben.

Vor den Haffmündungen kommen noch vor: *Crucigenia fenestrata, C. tetrapedia, Dictiosphaerium ehrenbergianum, Scenedesmus obliquus, Bohlinia echidnia* und *Trochiscia clevei.*

Heterokontae.

Während *Botryococcus braunii* im Kurischen Haff nur vereinzelt vorkommt, tritt die Form von Juli bis Oktober im Frischen Haff, vor der ostpreussischen Küste stellenweise reich entwickelt auf und ist auch noch auf der Hochsee anzutreffen. Sonst kommen nur vereinzelte

Cladophora- und *Enteromorpha*-Fäden sowie *Prasiola* Aplanosporen vor.

Cyanophyceen.

Die reiche Entwicklung von *Aphanizomenon flos aquae* im Gebiet erwähnte ich bereits. Sie beginnt im Juni im Haff, klingt im Oktober ab, wo sie auf der Hochsee ihr Maximum erreicht. Der Übergang vom Süsswasser zum Salzwasser bedeutet für sie demnach keine Schranke. Eine Schädigung der Fäden, die aus dem Kurischen Haff in die Ostsee gelangt waren, konnte ich nicht beobachten. Auch andere Cyanophyceen zeigen die gleiche Verbreitung. Die Gattung *Microcystis* mit *M. aeruginosa* und *M. viridis* tritt im Juni bis Oktober in den Haffen und vor der ostpreussischen Küste in reicher Entwicklung auf. Dasselbe ist bei der Gattung *Gomphosphaeria* mit *G. lacustris* und bei *Coelosphaerium dubium, C. kützingianum* und *C. naegelianum* zu beobachten. Diese Formen gelangen gelegentlich wie auch die häufig sessil vorkommende *Merismopedia glauca* bis in die Hochsee. Von den *Nostoccalen* ist *Nodularia spumigena* als *forma genuina* vor der Küste bis in die Hochsee und im Frischen Haff in den Zonen, wo ein höherer Salzgehalt ist, vorhanden, als forma *litorea* im Süsswasser allein, vorwiegend im Kurischen Haff. Die Anabaenen sind typische Wasserblütenalgen der Haffe. *A. hassallii* stirbt in der Ostsee bald, nachdem sie das Haff verlassen hat, ab. *A. spiroides* dagegen gelangt bis in die Hochsee, ohne sich dort weiter zu vermehren. Die Entfaltung von *A. baltica* beginnt im Juli in den Küstenzonen der Ostsee und erstreckt sich dann bis zum Oktober bis in die Hochsee und bei eingehendem Strome in die Haffe, wo sie jedoch unter der Masse der anderen Anabaenen vollständig verschwindet. Die Lyngbyen fehlen auf der Hochsee. *L. limnetica* und *L. contorta* kommen in reicher Entwicklung während der Sommermonate in den Haffen und vor der ostpreussischen Küste vor, *L. aestuarii* nur vor der Samlandküste, insbesondere im Neukuhrener Hafen.

Diese Beobachtungen über das Vorkommen der häufigsten Plankter gestatten es bereits, sowohl einzelne Planktongemeinschaften zu erkennen, als auch die Zonen anzugeben, die diese vorwiegend besiedeln. Eine noch eingehendere Gliederung der Planktongemeinschaften und Einteilung der Lebensräume wäre durch die Bestimmung der Flagellaten, insbesondere der Gymnodinien und Glenodinien, und Ciliaten möglich. Insbesondere könnten dann die Mündungszonen der kleinen Bäche des Samlandes umgrenzt werden. Eine derartige Untersuchung lässt dann aber auch die eingehende Berücksichtigung der anderen Plankter zweckmässig erscheinen, was wiederum die Notwendigkeit quantitativer Bestimmungen verlangt.

Vor der ostpreussischen Küste kommen drei Planktongemeinschaften vor:

1. Plankter aus dem Gebiet der Hochsee.
2. — aus der Küstenzone.
3. — aus den Haffen.

Mit ihrer Hilfe lassen sich gewisse Zonen im Untersuchungsgebiet feststellen, deren jeweilige Grenzen durch quantitative Bestimmungen festgesetzt werden müssen.

1. Das Hochseegebiet.

Wichtigste Zooplankter: *Centropages hamatus, Acartia bifilosa, Podon intermedius, Synchaeta fennica, Trichocerca marina, Tintinnopsis campanula* + var. *cyathus.*

Wichtigste Phytoplankter: *Coscinodiscus oculus iridis, Coscinodiscus radiatus, Chaetoceros borealis, Chaetoceros brevis, Dinophysis ovum* var. *baltica, Dinophysis acuminata.*

Eine weitere Gliederung der Zone ist nach dem ± starken Auftreten von Küstenformen und Haffplanktern möglich.

2. Das Küstengebiet.

(a) unter Einfluss von Strömungen, die keine Haffwasser mitsichführen.

Wichtigste Zooplankter: *Temora longicornis, Evadne nordmanni, Synchaeta monopus, Synchaeta baltica, Helicostomella subulata.*

Wichtigste Phytoplankter: *Melosira moniliformis, Melosira jürgensi, Achnanthes taeniata, Chaetoceros crinitus, Chaetoceros wighami, Navicula salinarum, Navicula peregrina.*

Eine weitere Gliederung ist nach dem Einfluss der Hochseeplankter möglich.

(b) unter Einfluss von Strömungen, die Haffwasser führen.

Wichtigste Zooplankter: *Eurytemora affinis, Brachionus capsuliflorus* var. *cluniorbicularis.*

Wichtigste Phytoplankter: *Coscinodiscus rothii* var. *subsalsa, Coscinodiscus lacustris, Cosc. jonesianus* var., *Nodularis spumigena* f. *genuina.*

3. Das Gebiet der Haffmündungen.

(a) mit vorwiegendem Auftreten von Ostseeplanktern.

Wind und Strömungen verursachen ein Aufstauen des Wassers, das aus dem Haff ausströmt, und Eindringen von Ostseewasser aus dem Küstengebiet. Die salzreichen Wassermassen dringen im Frischen Haff weit, im Kurischen Haff auf verhältnismässig geringe Strecken, ein und mischen sich mit dem Haffwasser. Im Kurischen Haff bildet sich jedoch keine Mischungszone für längere Zeit aus, wohl aber im Frischen Haff. Hier fehlt nach dem Nogatabschluss der Druck abfliessender Wassermassen, sodass sich weite brackige Zonen im Haff gebildet haben

(polyhaline Zone nach Willer, 1926). Obschon die Plankter der Zone 2b hier eine Massenentfaltung haben, kennzeichnet das Auftreten von Haffplanktern in grösserem Umfange wie im Küstengebiet diese Zone. Neben den Planktern der Zone 2b treten häufig auf:

Zooplankter: *Diaptomus graciloides, Leptodora kindtii, Diaphanosoma brachyurum* var. *leuchtenbg., Keratella cochlearis, Filinia longiseta.*

Phytoplankter: *Coelosphaerium naegelianum, Scenedesmus quadricauda, Tetrastrum multisetum* + var. *punctatum, Oocystis solitaria, Oocystis submarina.*

Massenentwicklungen, wie diese Formen in der folgenden Haffzone (mesohaline Zone nach Willer, 1926) erreichen, haben sie in dieser Zone jedoch noch nicht. Haffplankter, die Leitformen der Haffzone mit überwiegendem Süsswassereinfluss (oligohaline Zone nach Willer) sind, gelangen überhaupt nicht zur Zone 3a. Es handelt sich um:

Zooplankter: *Bosmina coregoni, Bosmina longirostris, Daphnia spez. spez., Ceriodaphnia spez. spez.*

Phytoplankter: *Chroococcus dispersus, Crucigenia rectangularis.*

(b) mit vorwiegendem Auftreten von Haffplanktern.

Im Mündungsgebiet des Kurischen Haffes ist nach meinen Feststellungen (Schmidt-Ries, 1939) zumeist Haffwasser mit Haffplanktern. Gelangen Ostseeplankter in das Haff, bilden sie nur für kurze Zeit und vorübergehend eine Zone 3a aus (s. Szidat, 1926; Willer, 1931, 1932; Schmidt-Ries, 1939). In Zone 3b treten neben vereinzelten Ostseeformen wie *Eurytemora affinis, Coscinodiscus rothii* var. *subsalsa, Cosc. lacustris, Nodularia spumigena* f. *genuina* Haffplankter auf, die ich bereits als Indikatoren stärkster Aussüssung des Gewässers im Frischen Haff bei 3a anführte. Eingehender gehe ich auf die Bildung von Zonen im Kurischen Haff in einer speziellen Arbeit ein (Schmidt-Ries, 1939).

Zusammenfassung.

Methodische Feststellungen.

1. Zur quantitativen Bewertung kleiner Plankter, die vor der ostpreussischen Küste auftreten, kommt nur eine Kammermethode, insbesondere die von Utermöhl, in Frage.
2. Sie kommt weiterhin allein für die Bewertung aller anderen Plankter in Betracht, da sie mit Hilfe der Fehlerberechnung eine einwandfreie Bestimmung der Planktonverhältnisse gestattet.
3. Ebensowenig wie eine zufallbedingte Zergliederung des Planktons in Netz-, Zentrifugen-, Pumpenplankton oder subjektiv gewählte Einteilung in Megalo-, Macro-, Micro-, Nannoplankton usw.

berechtigt ist, ist eine zufallsbedingte und willkürliche Auswahl einzelner Planktongruppen als Repräsentanten des Gesamtplanktons zulässig.

4. Oberflächenfänge allein geben keine zuverlässigen Angaben. Es muss möglichst eingehend die gesamte Wassersäule berücksichtigt werden.

Biologische Feststellungen.

1. Die von mir vor der ostpreussischen Küste beobachteten Plankter werden in einer Liste angegeben.
2. Ihre jahreszeitliche Entwicklung wird dargestellt.
3. Ihre örtliche Entwicklung wird im einzelnen angegeben, die Lebensgemeinschaften zusammengefasst und ihre Verbreitung im Untersuchungsgebiet nach Zonen gekennzeichnet.

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The Distribution of Chaetognatha in Scottish Waters in 1937.

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IN the year 1937 the species of *Sagitta* in Scottish waters were confined within stricter limits than in 1936, so much so that more stress can be laid on the deductions and it is perhaps of value to publish the major details, which should be read in conjunction with the 1936 results (Fraser, 1937).

The material was taken from the stations sampled by the "Explorer" with cheesecloth nets, 1 metre in diameter and towed horizontally at the surface and down to 100 metres in depth. These stations were supplemented by 2-metre cheesecloth vertical hauls from 200 metres in the Faroe Channel where horizontal hauls were not so frequent.

The distribution of *Sagitta elegans elegans* (Chart I, circles) confirms the statement that it is chiefly abundant where there is a mixture of Atlantic and coastal waters, and that on the east Scottish coast it is an indicator of admixture of Atlantic water, but on the west coast it is rather an indicator of coastal water. As in 1936, it was absent in the Faroe Channel, rare north of Shetland, much less common off the west coast and Hebrides than in the Minch or lochs and bays, fairly common close around the Faroe Islands and chiefly abundant off the Aberdeenshire coast. Although sparsely distributed in the southern and middle North Sea it was never abundant there and a line of demarcation was easily recognizable, probably therefore representing the southern limits of the northern North Sea drift currents. It is possible that the few *S. elegans* found near St. Kilda (at rectangles UU12 and VV14 — see chart) originated in the fringe of the Irish coastal waters and had been carried north by the North-East Atlantic drift. The dense concentration close to the Aberdeenshire coast and the absence of any numbers of *S. elegans* off the Northumbrian and Berwick coasts seem to show that the influx did not penetrate to any appreciable extent south of 56°N., and that the stream current, see chart by Tait (1934), extending as far south as

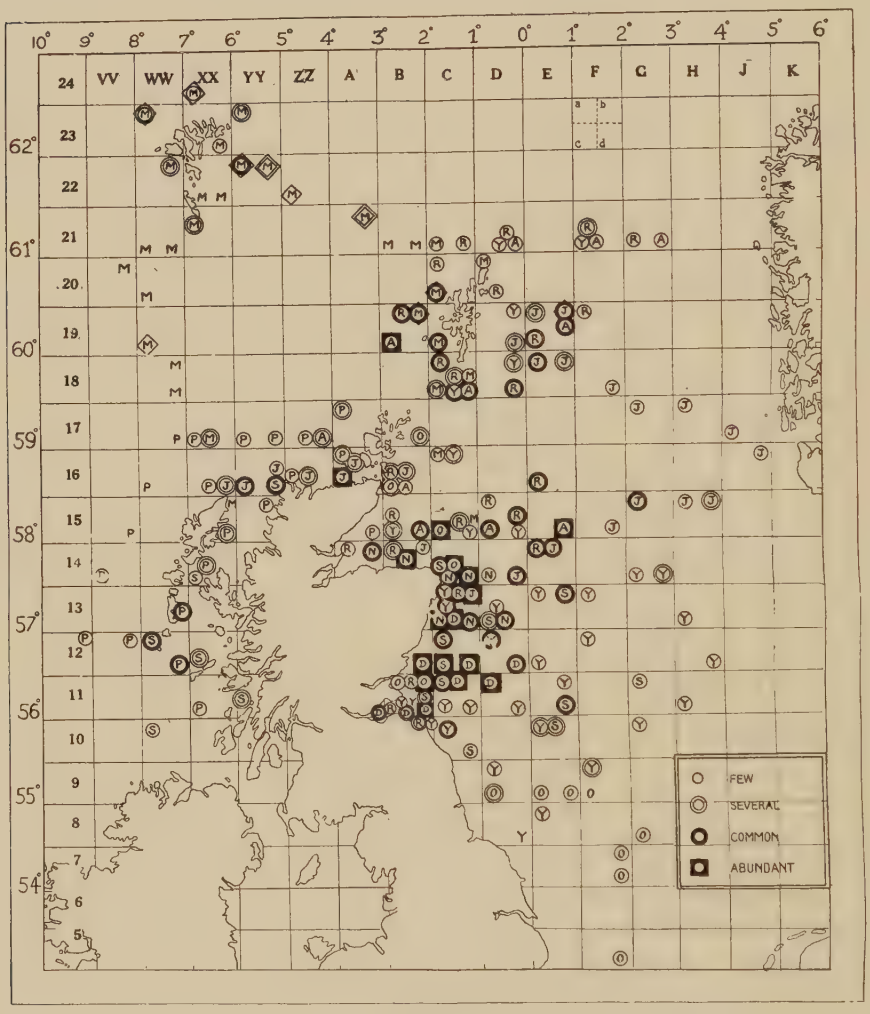

Chart I. The distribution of *Sagitta elegans elegans* (circles) and *S. elegans arctica* (diamonds) in Scottish waters in 1937. — Each station sampled is indicated by a letter representing the month of sampling, and for convenience is drawn to the nearest sub-area (i.e., an area of ½° longitude and ¼° latitude). The letter has then been ringed according to the numbers of individuals present, an unringed letter indicating absence. The letters used are: R = March, P = April, M = May, J = June, Y = July, A = August, S = September, O = October, N = November, D = December.

the Tees and then turning north along the Northumberland coast was apparently absent in 1937. *S. elegans* was not abundant within the Firth of Forth, so that apparently little influx entered there from the north.

Towards the end of the year the *Sagitta elegans* off the east Scottish coast were of an enlarged type, much more opaque than the typical form and with a greatly enlarged collarette. In spite of their larger size no trace of ovaries could be found in any specimens and the seminal vesicles were only very occasionally noticeable as a slight thickening near the tail fin. In November 1936 an isolated patch of this form was found in the Firth of Forth and from its measurements and head armature it was recorded as *S. elegans arctica.* It was assumed that as the Firth of Forth is a biological community separated from the North Sea, these had developed from a few specimens. It is inconceivable, however, that the large bulk of this form off the Aberdeenshire coast in December 1937 could have developed in that way to the exclusion of *S. elegans elegans,* or that such numbers could have been brought into the area by the influx without their course being recognized earlier. It follows, then, that this is not a separate sub-species of *S. elegans* but merely an enlarged form, perhaps a winter brood of *S. elegans elegans* and cannot therefore be *S. elegans arctica.*

A number of specimens of another variety of *S. elegans* were found in 1937. These specimens are still noticeably larger than the normal *S. elegans elegans,* commonly reaching up to 30 mm. or over, more hyaline (but not flaccid) and slightly iridescent when fresh. The collarette is entirely or almost entirely absent, and the ovaries are very long, reaching up to about half the length of the body even when the seminal vesicles are but slightly differentiated. Apart from these differences the characters are typically those of *S. elegans:*— fin arrangement, corona, tooth and seizing jaw formulae, gut diverticulae etc. It never occurred in abundance, but from the positions at which it was found (Chart I, diamonds) and at times associated with the salps *Cyclosalpa bakeri* and *Salpa asymmetrica,* it is evident that it is much more oceanic in habit than *S. elegans elegans.*

S. elegans baltica was not found in 1936 or 1937.

There are, then, three forms of *S. elegans* found in Scottish waters. One of these, the most abundant, is the typical *S. elegans elegans.* Both the other two have *arctica* characters in that they are enlarged and the head armature formulae overlap. One of these, that found on the east Scottish coast in December 1937 and in the Firth of Forth in November 1936, is very opaque, has a greatly developed collarette, and the ovaries appear to be undeveloped. This has now been shown to be merely a brood of *S. elegans elegans,* but whether they are able to produce typical forms or whether they die out leaving a new generation to be developed from the population of the spring influx is not yet clear. The other variety found round Faroe, the Faroe Channel and northern districts is much more hyaline, has little or no collarette and elongated ovaries. Although its oceanic distribution

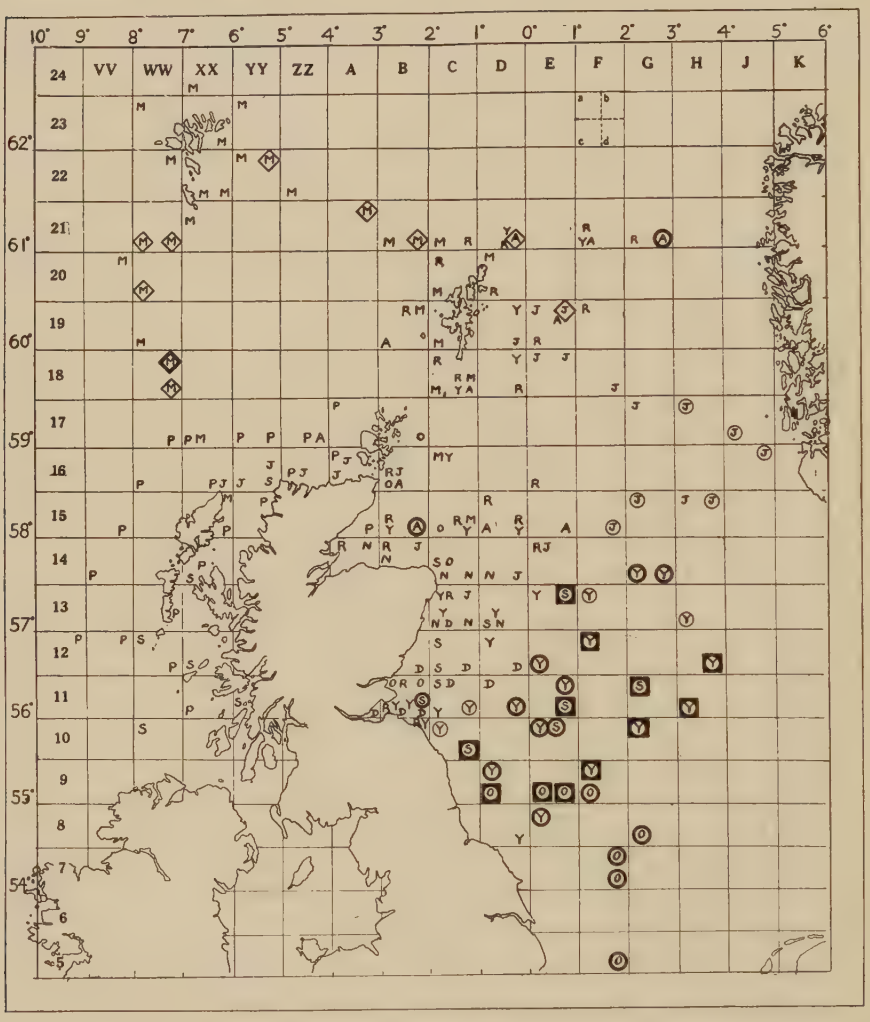

Chart II. The distribution of *S. setosa* (circles) and *S. maxima* (diamonds) in Scottish waters in 1937. Explanation as in Chart I.

appears from the chart to be rather spasmodic, its occurrence was each time associated with quite an appreciable drop in temperature, especially below the surface, compared with the stations on either side at which *Sagitta maxima* or *S. serratodentata* were found. There seems little doubt that this hyaline, slightly iridescent form is *S. elegans arctica* Aurivillius. The following table shows the temperature at the surface and at 100 metres depth across the Faroe Channel and around Faroe, omitting those stations close inshore.

Rectangle	Temperature Surface	100 m.	
C21c	9·81°C.	8·24°C.	
B21d	9·78	8·71	
B21c	9·45	8·29	
A21b	6·07	2·70	*S. arctica* present.
ZZ22c	8·67	7·82	do.
YY22b	8·69	7·57	do.
YY22a	8·04	6·60	do.
YY23a	8·31	7·53	
XX24c	7·66	7·59	*S. arctica* present.
WW23a	7·64	7·65	do.
WW21d	10·10	8·85	
WW21c	9·03	8·26	
VV20b	9·60	8·73	
WW20c	9·92	8·92	
WW19c	9·61	7·87	*S. arctica* present.
WW18b	10·50	9·54	
WW18d	10·48	9·59	
XX17c	11·16	8·95	

It will be seen that with one exception (in rectangle YY 23 a) *S. arctica* was found each time and only when the temperature at 100 metres was below 8·00°C.

It is still uncertain whether *S. arctica* should be considered a valid sub-species as all intermediate stages from one variety to another are to be found, though usually in comparatively small numbers, and no single constant character can be used in separating them. According to Michael (1919) *S. elegans elegans* from the American coast has no collarette. The presence of a small collarette in the European type and a greatly enlarged collarette in the winter brood would suggest that variations of this nature are not of great specific value. Enlarged size is usually considered related to colder surroundings and in *Sagitta* there appears to be some confirmation of this. The more flaccid species, *S. maxima, S. hexaptera* etc. belong to the deeper waters of the open ocean, while the more rigid species, *S. serratodentata, S. elegans, S. setosa,* etc. belong to the surface or shallow waters.

It is possible that in these variable characters of *Sagitta* we have a useful guide to the conditions in which they normally live and so in turn to tracing the origin of the water in which they are found. This would be especially true if the sub-species of *S. elegans* were varieties, changeable from one generation to another according to the particular conditions in which the young were hatched.

The distribution of *S. setosa* in 1937 (Chart II, circles) was much more clearly marked than in 1936. Its limits in 1937 were south and east of a well-defined line drawn north-east from Berwick (the Scottish border). Their numbers gradually diminished further north and over the Norwegian Deep, but it extended at least as far as 61°N. in August, though in no great numbers north of 57°30′N. (the area of

probable Baltic influence and over the Norwegian Deep). This well-defined line corresponds with the southern limits of distribution of abundant *S. elegans,* for although in small numbers *S. elegans* was very general in the North Sea, the area of its abundance fell distinctly to the north and west of the *S. setosa* and there was little real mixing. At each of those few stations where both species were found, *S. setosa* was concentrated at the surface and *S. elegans* and its associated richer plankton was found below, a feature again noticed in more recent collections of 1938.

S. setosa did not penetrate into the Firth of Forth in 1937 — still farther evidence of the individuality of that community. The few specimens found in August in the Moray Firth probably represent the centre of the Moray Firth eddy (T a i t 1934).

S. hexaptera. A few rather meagre specimens of this species were taken north-west of the Faroes in May.

S. maxima (Chart II, diamonds) was found in rather less numbers in 1937 than in 1936, but had a similar distribution. It is brought from deep water into the Faroe-Shetland Channel, and the upwelling on the edge of the shelf brings it into the surface waters where it soon perishes. It was found along the line of stations from the Faroes to the Butt of Lewis and at isolated stations round the north of Shetland, but not elsewhere[1]).

S. serratodentata (Chart III, circles) had a similar distribution in 1937 to that in 1936, i.e., it had a surface oceanic habitat, and was found off the west coast of Scotland, but not between the Outer Hebrides and the mainland, less commonly in the Faroe Channel and north coast of Scotland, but not in the immediate neighbourhood of the Faroes, and in dwindling numbers near the Shetlands. No specimens were found within the North Sea in 1937.

Eukrohnia hamata (Chart III, diamonds) occurred in much greater numbers in 1937 than in 1936. It was found in the Faroe-Shetland Channel and round the Faroes, and was also taken in fair numbers at one station west of Faroe Bank. It was less common west of the Butt of Lewis. Although of a somewhat similar distribution to *S. maxima,* it rarely occurred in the same collections.

The pushing of *S. setosa* further south and east than in the previous year, and the distribution of *Sagitta* generally, indicates that in 1937 a greater volume of oceanic influx penetrated into the Scottish area than in 1936. This influx brought with it Salps, Doliolids, *Rhincalanus, Euchirella, Pleuromamma robusta, Physophora, Sagitta serratodentata, S. maxima, S. hexaptera, S. arctica* and *Calanus hyperboreus.* Thus a mixture of cold and warm water forms was again found south-west of the Faroes, illustrating an arctic influx there, but with warm water forms predominating. North of the Shetlands a greater proportion of cold water species was found, notably *Calanus hyperboreus, Metridia longa* and *Sagitta arctica,* and many of the oceanic forms had by then

[1]) *Sagitta lyra* was also found together with *S. maxima* in this area in 1938.

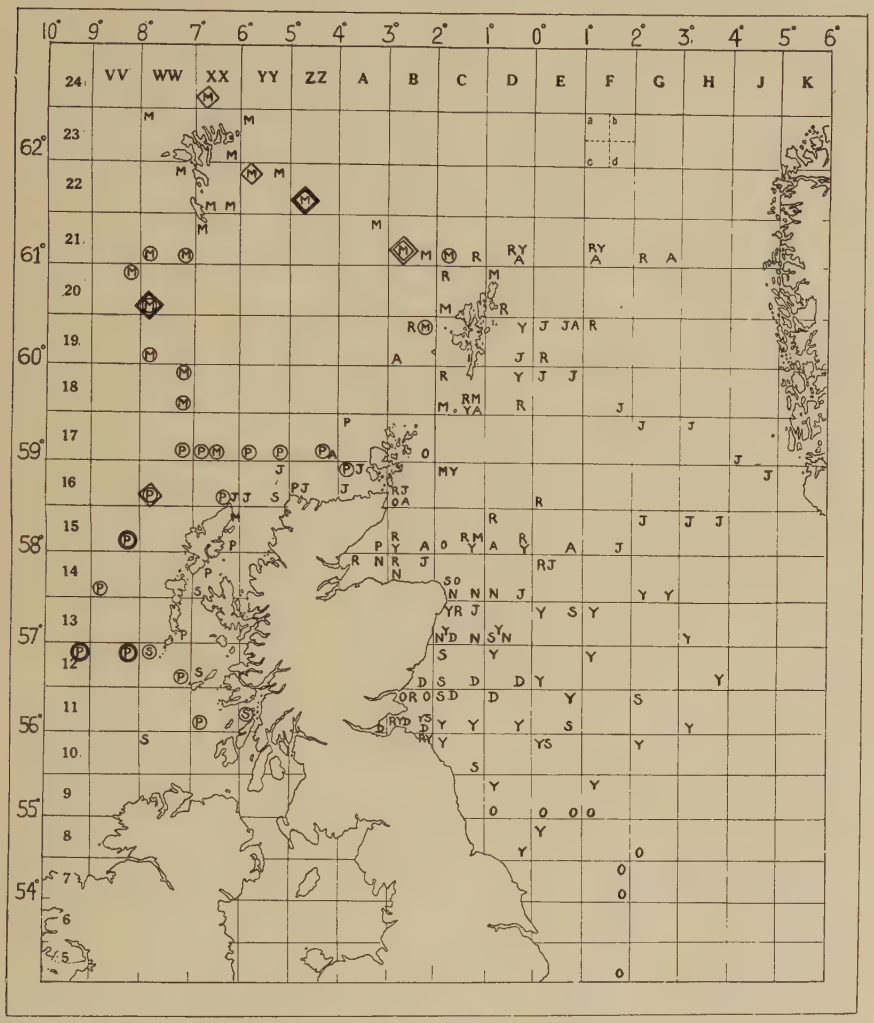

Chart III. The distribution of *S. serratodentata* (circles) and *Eukrohnia hamata* (diamonds) in Scottish waters in 1937. Explanation as in Chart I.

died out, indicating an increase in the arctic influence. The relatively small numbers of salps and doliolids and other warm water exotics from far afield, and the abundance of *Physophora* and other temperate oceanic forms in the north-east Atlantic, together with the presence of *Calanus hyperboreus* as far south as Kinnaird Head and the absence of *S. serratodentata* in the North Sea indicates that although the 1937 influx was greater than in 1936 it also contained a greater arctic influence.

These conditions are also reflected in the plankton collections made off Plymouth. Catches of *S. elegans* and *S. setosa* were both low and *Rhincalanus* and salps appeared at the western end of the English Channel, the former noticed for the first time and the salps occurring for the first time since 1932 (Russell 1938). This probably means that the general trend of the North Atlantic drift approaching the British coasts was further south than usual, thus allowing a greater arctic influence to effect the more northerly areas.

In the North Sea the influx, by this time a mixture of oceanic and coastal water and containing an abundance of *S. elegans*, was concentrated on the Aberdeenshire coast. Associated with this mixture of *S. elegans* was a rich plankton with an abundance of *Calanus finmarchicus, Thysanoessa, Themisto* and *Aglantha*, and fair numbers of young fish. Other medusae were also found in moderate numbers and included *Tima, Laodicea, Cosmetira, Halopsis, Bougainvillia, Rathkea* and *Staurophora*. It is this mixture of coastal and oceanic water that seems to be most favourable to the breeding of most of those indigenous crustacean species that are so valuable as food forms and it thus makes a rich feeding area.

There are, then, three distinct water masses each with its own fauna of *Sagitta* and other indicator species. They are — I. the entering oceanic water containing a mixture of warm and cold water forms, *S. maxima, S. hexaptera, S. serratodentata, S. arctica*, etc.; II. the mixture of coastal and oceanic water containing a rich plankton with *S. elegans;* III. the pure North Sea water with *S. setosa*. There is no clear division between the first and second of these as there is a gradual change from one to the other, but between the second and third the boundary is quite distinct and where there is overlapping the mixed water is below and the southern North Sea water is above.

Those familiar with Russell's series of papers will see at once the similarities between the distribution of *Sagitta* in the Scottish and English Channel areas, the relationship between the two, and the consequent deductions. The three water masses have their exact counterparts off the western end of the English Channel. They are Russell's — I. "South-Western Water" containing salps, doliolids, *Muggiaea, Liriope* etc., II. "Western Water" containing a rich fauna of *S. elegans, Aglantha, Cosmetira, Themisto, Clione* (and in years of strong inflow only, *S. serratodentata)*, III. "Channel Water" containing *S. setosa* and the absence of the rich fauna associated with *S. elegans*.

Thomsen (1933) shows that the water invading the North Sea brings with it an increased concentration of both nitrates and phosphates. Intensive mixing on the edge of the shelf will cause the higher phosphate and nitrate concentration from the deep water to be brought to the surface, and this, through a large spring and autumn diatom increase, will be responsible, directly or indirectly, for the rich nature of the *elegans* water.

Although in the main the distribution of plankton indicator species agrees with the distribution of different physical water masses,

differences may from time to time be noticed. Where two neighbouring water masses have similar temperatures and salinities but an entirely different plankton content, a difference of medium of more profound effect on the biological community and fish population is present than a slight physical change with biological similarity. The actual physical change of one or two degrees of temperature or parts per thousand of salinity will not be of vital effect unless accompanied by a biological change of conditions, and where such a change has taken place it will be revealed by the plankton more readily than by any other means owing to the many diverse species and many diverse combinations of species that make up plankton. Plankton is at the same time abundant enough to enable adequate sampling to be made in a few minutes. Most plankton animals are themselves quite eurythermal and euryhaline enough to withstand fairly big physical changes without hurt, showing that the very distinct separation of forms from one water mass to another does mean some biological change that at present cannot be defined in chemical and physical terms, and yet nevertheless is a very real change and of vital importance. It is in the location of such subtle distinctions that the value of this type of research lies.

Summary.

The 1937 distribution of *Sagitta* in Scottish waters confirms the deductions made from the 1936 material. *S. elegans elegans* is entirely absent from the entering oceanic water but becomes more and more abundant as this water becomes mixed with coastal water. Thus it was absent from the Faroe Channel, and rare off the west coast of Scotland, but more common in Faroese waters and close to the Shetlands and also in the Minch and west coast lochs, but was chiefly abundant in the northern North Sea off the east Scottish coast. *S. elegans arctica* was found in small numbers at the western entrance to the Faroe Channel and rather more commonly between the Faroes and the Shetlands, indicating the presence of an arctic influence west of Faroe which becomes stronger between Faroe and Shetland. This is also illustrated by other plankton indicator species.

The line of demarcation between *S. elegans elegans* and *S. setosa* in the North Sea was very clearly marked in 1937 and was much further south than in 1936.

S. maxima and *S. serratodentata* had similar occurrences in 1937 to those in 1936, but *Eukrohnia hamata* was much more abundant in 1937.

The 1937 material confirms the deductions made from the 1936 material, and once again the relationship with the Plymouth distribution of plankton is clear.

The value of locating subtle distinctions between water masses by means of plankton indicators is discussed briefly.

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Marking Experiments on Lemon Soles at Faroe 1923—1936, with a Note on Icelandic Markings 1925.

By

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Introduction.

FROM 1910 to 1912 marking experiments on plaice and lemon soles were carried out by the "Kommissionen for Danmarks Fiskeri- og Havundersøgelser" at the Faroes. The work, described by Strubberg (2), was mainly concerned with plaice, however, and the lemon soles, which were marked, were liberated within territorial waters in Westmanhavn Fjord.

During the period 1923 to 1936 the Scottish research vessel "Explorer" paid nine visits to Faroese waters. On each occasion marking experiments on lemon soles were carried out in conjunction with similar work in Scottish waters. The results of the Scottish experiments have already been described in a paper (1) which deals with several points relating to the method of capture of the fish, the marking operations, the treatment of the recaptured fish etc., which require no repetition in the present paper.

For a comprehensive study of the results of work of this nature it would be necessary to carry out marking experiments at all seasons throughout several successive years. For obvious reasons this is impossible, but some knowledge regarding the survival capacity and migrations of the species may be obtained from these intermittent experiments carried out almost entirely during the spring and early summer.

Experiments—Size and Age of Fish Marked.

In all, 964 lemon soles were marked in a series of 40 experiments details of which are contained in Table 1. All the fish utilized were caught and liberated in extra-territorial waters at positions as close as possible to their place of capture.

Table 1.

Marking Experiments on Lemon Soles, Faroe 1923—1936.

Year	No. of Experiment	Liberation Date	Liberation Position	Area	Depths (metres)	Number Liberated	Number Recaptured
1923	14	25. April	62°12′N. 6°24′W.	XX23d	80	26	0
1924	6	14. May	62°20′N. 7°33′W.	WW23a	108	27	5
	7	15. „	62°34′N. 6°40′W.	XX24c	113	36	6
	8	17. „	62°15′N. 6°11′W.	XX23b	100	27	12
	9	17. „	62°26′N. 6°21′W.	XX23b	62	51	1
1927	37	13. August	62°19′N. 6°03′W.	XX23b	88	4	2
	38	14. „	62°34′N. 6°40′W.	XX24c	97	62	10
	39	15. „	61°43′N. 7°05′W.	WW22d	84	7	1
	39a	15. „	61°41′N. 7°19′W.	WW22d	133	8	2
1929	8	18. May	62°12′N. 6°11′W.	XX23d	100	34	9
	9	18. „	62°20′N. 5°55′W.	YY23a	104	9	4
	10	19. „	62°28′N. 6°35′W.	XX23a	90	27	0
	17	27. June	62°37′N. 6°33′W.	XX24c	110	60	6
1931	20	19. May	61°45′N. 6°26′W.	XX22b	92	22	7
	21	19. „	61°46′N. 7°11′W.	WW22b	97	2	1
	22	19. „	61°36½′N. 7°18′W.	WW22d	146	3	1
	23	20. „	61°59′N. 7°50′W.	WW22a	119	4	3
	24	20. „	62°04½′N. 8°03′W.	VV23d	119	7	3
	25	20. „	62°16′N. 7°32′W.	WW23a	99	25	8
	26	21. „	62°28′N. 6°35′W.	XX23a	97	6	1
	27	21. „	62°33′N. 6°35′W.	XX24c	100	5	2
	28	21. „	62°20′N. 5°55′W.	YY23a	100	10	5
	29	22. „	62°16′N. 5°45′W.	YY23a	103	35	17
	30	22. „	62°12′N. 6°11′W.	XX23d	108	31	13
	31	27. „	60°47′N. 8°12′W.	VV20b	213	6	0
1933	4	11. June	61°45′N. 6°26′W.	XX22b	74	16	3
	5	13. „	62°12′N. 6°11′W.	XX23d	104	68	22
	6	14. „	62°16′N. 7°32′W.	WW23a	100	68	14
	7	14. „	61°46′N. 7°11′W.	WW22b	94	78	13
1935	1	10. „	62°16′N. 7°32′W.	WW23a	103	12	1
	2	11. „	61°58′N. 7°52′W.	WW22a	115	20	8
	3	14. „	62°34′N. 6°37′W.	XX24c	102	6	1
	4	14. „	62°20′N. 5°55′W.	YY23a	94	30	10
	5	15. „	62°12′N. 6°11′W.	XX23d	113	31	1
1936	20	4. „	60°59′N. 8°16′W.	VV20b	175	12	1
	21	4. „	61°17′N. 6°58′W.	XX21a	152	14	0
	22	4. „	61°45′N. 6°26′W.	XX22b	94	17	6
	23	10. „	62°21′N. 5°46′W.	YY23a	119	17	7
	24	12. „	62°24′N. 7°07′W.	WW23b	106	10	1
	25	12. „	62°16′N. 7°32′W.	WW23a	100	31	0

The fish, measured to the nearest centimetre, ranged from 17 to 46 cm. with the following frequencies in 5 cm. groups:—

Table 2.

Size Frequencies of Lemon Soles marked at Faroe 1923—1936.

Size Group	<21	21—25	26—30	31—35	36—40	>40
Liberated	47	215	280	251	142	29
Recaptured	3	25	69	75	41	4
%	6·4	11·6	24·6	29·9	28·9	13·8

The percentages of recaptures in the various size-groups resemble the corresponding figures for the experiments in Scottish waters in being low for the smaller size-groups and in becoming greater for the larger sizes. In each group, however, the percentage of recaptures is greater than in Scottish waters.

By examining samples of scales taken at liberation the ages of the fish were determined as follows:—

Table 3.

Age Frequencies of Lemon Soles marked at Faroe 1923—1936.

Year	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+	12+	13+	14+	?
Number	8	167	197	144	189	87	61	54	31	15	4	2	4	1

Table 4.

Numbers of Lemon Soles Liberated and Recaptured, Faroe 1923—1936.

Year	1923	1924	1927	1929	1931	1933	1935	1936	Total	
Month	April	May	Aug.	May-June	May	June	June	June	lib. **rec.**	%
Area										
YY23a	—	—	—	9	45	—	30	17	101	
	—	—	—	**4**	**22**	—	**10**	**7**	**43**	43
XX23a	—	—	—	27	6	—	—	—	33	
	—	—	—	—	**1**	—	—	—	**1**	3
23b	—	78	4	—	—	—	—	—	82	
	—	**13**	**2**	—	—	—	—	—	**15**	18
23d	26	—	—	34	31	68	31	—	190	
	—	—	—	**9**	**13**	**22**	**1**	—	**45**	24
XX24c	—	36	62	60	5	—	6	—	169	
	—	**6**	**10**	**6**	**2**	—	**1**	—	**25**	15
WW23a	—	27	—	—	25	68	12	31	163	
	—	**5**	—	—	**8**	**14**	**1**	**10**	**38**	23
23b	—	—	—	—	—	—	—	10	10	
	—	—	—	—	—	—	—	**1**	**1**	10
VV23d	—	—	—	—	7	—	—	—	7	
	—	—	—	—	**3**	—	—	—	**3**	43
WW22a	—	—	—	—	4	—	20	—	24	
	—	—	—	—	**3**	—	**8**	—	**11**	46
22b	—	—	—	—	2	78	—	—	80	
	—	—	—	—	**1**	**13**	—	—	**14**	18
22d	—	—	15	—	3	—	—	—	18	
	—	—	**3**	—	**1**	—	—	—	**4**	22
XX22b	—	—	—	—	22	16	—	17	55	
	—	—	—	—	**7**	**3**	—	**6**	**16**	29
XX21a	—	—	—	—	—	—	—	14	14	
	—	—	—	—	—	—	—	—	—	0
VV20b	—	—	—	—	6	—	—	12	18	
	—	—	—	—	—	—	—	**1**	**1**	6
Total	26	141	81	130	156	230	99	101	964	
	—	**24**	**15**	**19**	**61**	**52**	**21**	**25**	**217**	
%	0	17·0	18·5	14·6	39·1	22·6	21·2	24·8	22·5	

Recaptures—Method and Ports of Landing.

Up to the end of 1938, 217 fish were recaptured out of the 964 which were marked and liberated. Table 4 (see p. 37) gives the numbers liberated and recaptured in each statistical area.

It is at once noticeable that the percentage of recaptures varies considerably from place to place and also from year to year. This is probably due to the time and place of the experiments in relation to the commercial fishery.

All the recaptures, with three exceptions (method of capture unknown), were made by trawlers using the otter trawl. With one exception, particulars of which were forwarded from Denmark, the recaptured fish were all caught by British vessels. Aberdeen contributed 143 of the total, Grimsby 59, Fleetwood 5, Hull 5, North Shields 3, and Hartlepool 1. Aberdeen vessels thus were responsible for the return of 66 % of the total. From this it might be supposed that this port obtained the bulk of landings of lemon soles from Faroe. The F.B.S. (5) and M.A.F. (4) statistics, however, reveal that from 1922—1936 the total weight of Faroese lemon soles landed in England varied from two to four times as great as the total landed in Scotland.

Table 5.

Landings in cwt. of Lemon Soles from Faroe.
1922—1936 by British Vessels.

Year	Scotland	England	Total
1922	3,806	8,868	12,674
1923	4,132	14,811	18,943
1924	4,145	16,260	20,405
1925	2,883	16,888	19,771
1926	5,391	11,306	16,697
1927	5,431	14,443	19,874
1928	4,378	12,908	17,286
1929	3,334	12,075	15,409
1930	6,676	17,128	23,804
1931	11,181	25,262	36,443
1932	11,889	27,754	39,643
1933	10,841	23,092	33,933
1934	7,434	16,978	24,412
1935	7,818	18,220	26,038
1936	8,828	14,429	23,257

Table 6.

Monthly Landings at Aberdeen.
From Faroe, 1936.

Month	No. of landings	Weight (cwt.)
I	43	129
II	38	182
III	71	387
IV	90	587
V	78	747
VI	201	2,565
VII	168	2,612
VIII	107	1,250
IX	65	518
X	43	203
XI	60	145
XII	44	89

The large proportions of marked lemon soles returned from Aberdeen must therefore be due to other causes. A detailed examination of the Aberdeen landings of lemon soles from Faroe for the year 1936, which may be taken as representative of the period under review, shows that Aberdeen trawlers frequent certain grounds such as those of Nolsö, Fuglö and Myggenæs which mainly lie within the statistical squares XX22b, XX23d, YY23a, WW23a, WW23b, where most of

the marking experiments have been conducted. Furthermore, a monthly analysis of the numbers of trawler landings with the total weights of lemon soles reveals a rapid rise to a peak in June, July and August which is followed by an equally rapid decline from September onwards (Table 6).

Thus it is clear that most of the marking experiments immediately preceded or coincided with the beginning of the main lemon sole fishery at Faroe by Aberdeen trawlers.

Maturities of Marked and Unmarked Fish.

Recaptures were made in each month of the year, although 43 % of the total recaptured was returned during June alone and 71 % during the months of May, June and July. On return to the laboratory the condition of the reproductive organs of each recaptured fish is noted in addition to other observations. The stages of maturity recognized are given in Table 7.

Table 7.

Maturities of Recaptured Lemon Soles.

Males

Months.	1	2	3	4	5	6	7	8	9	10	11	12
Immature	—	—	—	—	—	1	—	1	—	—	—	—
Maturing	—	3	—	—	3	6	—	—	—	—	—	—
Ripe	—	1	1	1	4	14	5	1	—	1	—	—
Spent	—	—	—	—	7	17	10	3	2	—	—	1
Spent and recovering	—	—	—	—	—	1	2	—	1	—	1	1

Females

Months.	1	2	3	4	5	6	7	8	9	10	11	12
Immature	—	—	—	—	—	3	—	—	—	—	—	—
Maturing	—	—	2	2	2	14	5	1	2	—	—	1
Ripe	—	—	—	2	4	14	4	1	1	—	—	—
Spent	—	—	—	—	1	8	9	2	2	—	—	—
Spent and recovering	1	—	—	—	—	—	2	—	—	—	—	2

Ripe males were found from February to October and ripe females from April to September, while spent males were obtained from May to December and spent females from May to September. The spawning season therefore coincides generally with the spawning in Scottish waters. Five fish were recaptured in the immature condition, which shows that a certain percentage of the fish used in marking experiments were immature. Further information on this point is gained by examining the maturities of all lemon soles caught at Faroe by the research vessel from 1923—1938 and not utilized for marking purposes. The following table (8) condenses the results for all areas except Faroe Bank, which, from preliminary work on the growth of lemon soles at Faroe, is seen to support a very poor growth-rate compared with the grounds round the islands.

Table 8.

Maturities of Lemon Soles caught at Faroe from April to July 1923—1938.

	5 cm. groups.							
Males.	11—15	16—20	21—25	26—30	31—35	36—40	41—45	46—51
Totals	49	79	57	87	88	60	16	—
Immature	13	7	1	3	—	—	—	—
%	26	9	2	3	—	—	—	—
Maturing	13	27	19	22	15	6	—	—
%	26	34	33	26	17	10	—	—
Ripe & Spent	23	45	37	62	73	54	16	—
%	48	57	65	71	83	90	100	—
Females.								
Totals	42	55	43	51	107	88	31	14
Immature	41	46	26	6	1	—	—	—
%	98	84	60	12	1	—	—	—
Maturing	1	6	15	27	44	31	7	—
%	2	11	35	53	41	35	23	—
Ripe & Spent	—	3	2	18	62	57	24	14
%	—	5	5	35	58	65	77	100

As the research vessel records refer to the period April to August there is little doubt that a large proportion of the ripening fish would also have spawned in the year of their capture had they survived. Thus, about 25 % of the males of 11—15 cm. in length was immature while at least 48 % of them reached maturity. Among the females on the other hand 98 % was definitely immature while not a single specimen of this size had attained maturity. In the 16—20 cm. and 21—25 cm. groups larger numbers of males came into the ripe and spent category while only a few of the females reached this stage and far more than half remained immature. In the period under survey the largest record of an immature male was 28 cm. and the smallest ripe fish 11 cm., while among the females the corresponding measurements were 32 cm. and 17 cm. respectively.

On Faroe Bank, however, where growth is poor, 18 male fish out of 21 (86 %) were ripe at 11—15 cm. while none was immature. Out of 14 females in the same size-group 7 were ripe and 6 immature. The maximum sizes for immature fish on these grounds were 16 cm. for males and 19 cm. for females while the minimum size for ripe fish was 11 cm. in each case.

In the size and maturities of lemon soles the grounds round the Faroes are comparable with those off the east coast of Scotland in the central North Sea, while the Faroe Bank resembles the Scottish grounds on the edge of the Atlantic slope, such as off Ronas Voe, North Rona and St. Kilda.

Period of Freedom of Marked Fish.

The period of freedom ranged from 0 to 1438 days, although there is some doubt regarding the reliability of the latter figure since the mark alone was recovered and no details were supplied. Another fish, however, was free for 1045 days. In the following table (9) are given the numbers of fish recaptured within each period of 100 days from the time of liberation.

Table 9.

Numbers of Marked Lemon Soles Recaptured per 100-Day Periods.

Days Free	1923	1924	1927	1929	1931	1933	1935	1936	Total
0— 100	—	12	1	6	51	41	14	21	146
100— 200	—	2	6	—	3	—	1	—	12
200— 300	—	1	6	7	1	2	—	2	19
300— 400	—	4	—	4	5	3	1	2	19
400— 500	—	1	1	1	1	3	4	—	11
500— 600	—	—	—	—	—	1	—	—	1
600— 700	—	3	—	—	—	—	—	—	3
700— 800	—	1	—	1	—	1	—	—	3
800— 900	—	—	—	—	—	—	—	—	—
900—1000	—	—	1	—	—	—	—	—	1
1000—1100	—	—	—	—	—	—	1	—	1
1100—1200	—	—	—	—	—	—	—	—	—
1500	—	—	—	—	—	1	—	—	1

In terms of years 182 were recaptured within a year of liberation; 30 more were recovered within two years and only 5 survived longer than two years. Of these 5 fish, 4 were taken during their third year of freedom and one doubtful specimen in its fifth year.

Of the 182 recaptured within a year 99 were recovered within a month of liberation and no less than 38 of these were taken within a week. Prior to 1931 no recaptures were effected within a week of liberation and only 9 out of a total of 58 returns were recovered within a month. This is partly explained by the marking experiments from 1923—9 being carried out in April, May and August, while from 1931 onwards the experiments were mainly conducted during June at the height of the fishing season.

Rate of Recapture of Marked Fish.

Although the percentage of marked fish of which no trace is received, due to various causes such as death from marking operations or natural causes or loss of marks or neglect to make returns, is large, the remainder may be regarded as a sample of the stocks in the sea. In order to study the rate of recapture of the marked fish percentages of the total liberated have been worked out for each 100-day period for the period 1923 to 1936 and also for 1923 to 1929 (omitting 1927) and for 1931 to 1936.

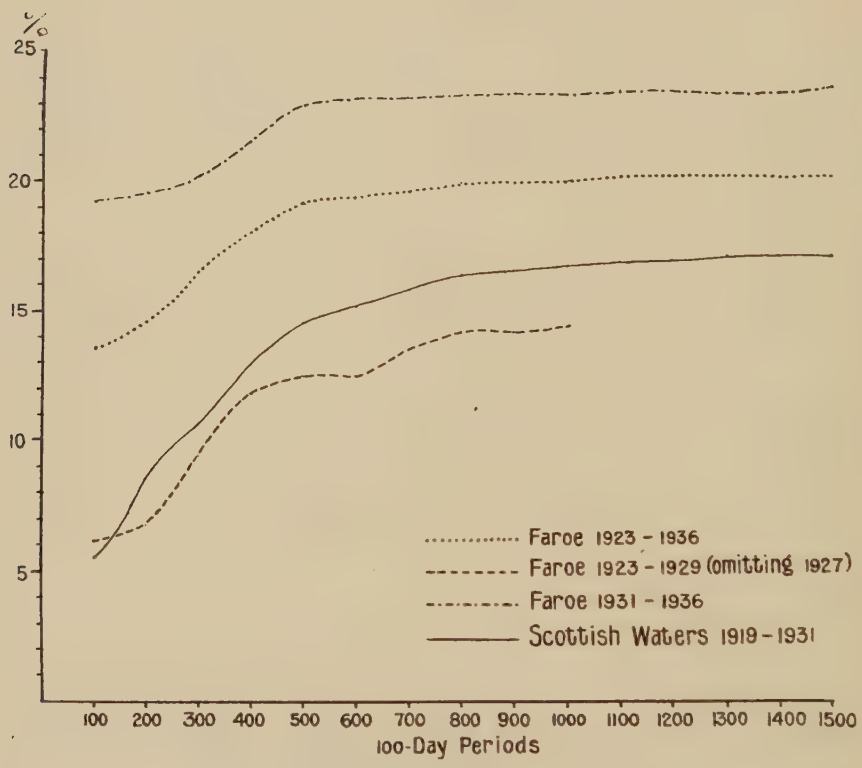

Fig. 1. Marked Lemon Soles, Faroe 1923—1936.
Percentage Rate of Recapture (Cumulative).

Table 10.

Percentage of Recapture of Marked Lemon Soles, 26 cm., and over.
100-Day Periods.

	1923, 24, 29.			1931, 33, 35, 36.			1923—1936 inclus.		
	No.	%	Σ	No.	%	Σ	No.	%	Σ
0— 100	18	6·08	6·08	107	19·14	19·14	126	13·46	13·46
100— 200	2	0·68	6·76	2	0·36	19·50	10	1·07	14·53
200— 300	8	2·70	9·46	3	0·54	20·04	17	1·82	16·35
300— 400	7	2·36	11·82	8	1·43	21·47	15	1·60	17·95
400— 500	2	0·68	12·50	8	1·43	22·90	11	1·18	19·13
500— 600	—	—	12·50	1	0·18	23·08	1	0·11	19·24
600— 700	3	1·01	13·51	—	—	23·08	3	0·32	19·56
700— 800	2	0·68	14·19	1	0·18	23·26	3	0·32	19·88
800— 900	—	—	14·19	—	—	23·26	—	—	19·88
900—1000	1	0·34	14·53	—	—	23·26	1	0·11	19·99
1000—1100	—	—	—	1	0·18	23·44	1	0·11	20·10
1100—1200	—	—	—	—	—	23·44	—	—	20·10
1500	—	—	—	1	0·18	23·62	1	0·11	20·21

As the percentage of returns for fish of less than 26 cm. is much smaller than for larger fish and also as varying percentages of fish below 26 cm. escape through the meshes of the ordinary otter trawl, only fish of 26 cm. and over have been considered in these calculations. The results are presented in Table 10 and the graphs derived from the cumulative percentages of recapture are given in Figure 1.

In comparing the results of the two periods 1923—9 and 1931—6 the most remarkable feature is the increase in the percentage of recaptures during the first 100 days of freedom in recent years. Prior to 1931 recaptures were frequent during the first 100 days, a year later and then two years later (see curve, Fig. 1). Since 1931, however, a big increase in the returns during the first 100 days is noticeable, which is followed by a much smaller return a year later. At the end of two years the percentage of returns is indistinguishable from those of other seasons of the year. It is clear therefore that few marked lemon soles of 26 cm. and over remain at liberty for more than two years and indeed it would appear that few survive a second summer fishing. In comparison with figures for Scottish waters (1919—31), where few recaptures are expected after four years, this reveals a much faster rate of recapture. As already stated most of the Faroe experiments were carried out in the regions of greatest fishery activity, thus giving extreme results. It must be borne in mind, however, that the experiments were mainly carried out on the chief lemon sole grounds and that the Faroese grounds are small in extent compared with the North Sea or Iceland.

There can be little doubt that the grounds at Faroe have been subjected to very heavy fishing activity since 1931. The result of the fishery from 1922 onwards is seen in the landings of lemon soles in Scotland and England (Table 5). In 1931 and 1932 these landings reach a maximum, since when a decline has taken place. The big landings for 1931 and 1932 though due partly to increased fishing effort are also explained by the emergence of an extraordinarily prolific brood of lemon soles at Faroe — that of 1927.

Migration.

The majority of the marked fish were captured within 15 miles of the position of liberation. From the periods of freedom, however, it is obvious that many of the fish did not have an opportunity of moving far had they been so inclined. A few records taken at distances of 15 to 29 miles show no marked directional movement. Twenty-four recaptures made at 30 miles or more from their position of liberation are regarded as migrants as in the Scottish experiments. Details regarding these fish, which form 11 % of the total recaptured, are given in Table 11.

Assuming that these fish travelled to their position of recapture by the shortest route, we find that 17 of the 24 show an anticlockwise movement northwards along the east coast, westwards along the north coast and southwards along the west coast (Chart 1).

Table

Lemon Sole Migrants.

No.	Liberation Date	Position	Area	Length cm.	Age
1	17.5.24	62°15′N. 6°11′W.	XX23b	36·0	10+
2	17.5.24	62°26′N. 6°21′W.	XX23b	41·0	9+
3	13.8.27	62°19′N. 6°03′W.	XX23b	38·0	6+
4	13.8.27	62°19′N. 6°03′W.	XX23b	38·0	6+
5	15.8.27	61°41′N. 7°19′W.	WW22d	34·5	9+
6	18.5.29	62°12′N. 6°11′W.	XX23d	34·5	8+
7	18.5.29	62°12′N. 6°11′W.	XX23d	25·5	5+
8	18.5.29	62°12′N. 6°11′W.	XX23d	34·5	8+
9	19.5.31	61°45′N. 6°26′W.	XX22b	35·1	5+
10	20.5.31	62°04½′N. 8°03′W.	VV23d	34·1	7+
11	20.5.31	62°04½′N. 8°03′W.	VV23d	25·0	4+
12	20.5.31	62°16′N. 7°32′W.	WW23a	22·7	3+
13	21.5.31	62°28′N. 6°35′W.	XX23a	29·8	4+
14	11.6.33	61°45′N. 6°26′W.	XX22b	36·1	6+
15	13.6.33	62°12′N. 6°11′W.	XX23d	30·6	6+
16	13.6.33	62°12′N. 6°11′W.	XX23d	33·0	6+
17	13.6.33	62°12′N. 6°11′W.	XX23d	28·6	3+
18	14.6.33	62°16′N. 7°32′W.	WW23a	25·7	3+
19	14.6.33	62°16′N. 7°32′W.	WW23a	37·7	6+
20	14.6.33	62°16′N. 7°32′W.	WW23a	20·3	3+
21	10.6.35	62°16′N. 7°32′W.	WW23a	29·4	5+
22	4.6.36	61°45′N. 6°26′W.	XX22b	34·0	7+
23	4.6.36	61°45′N. 6°26′W.	XX22b	30·2	6+
24	12.6.36	62°16′N. 7°32′W.	WW23a	25·2	3+

An examination of the current-system of the islands as demonstrated by T a i t (3) reveals that the prevailing water movements round the Faroes follow a clockwise direction. The movement of the 17 fish under consideration is thus contranatant in character and agrees with the migratory movement of lemon soles in Scottish waters.

On the west side of the islands 6 migrants penetrated south of 62°N., 5 of which were recaptured fairly close inshore. One individual, however, was retaken on Faroe Bank having travelled from the Outer Myggenæs grounds, a distance of at least 60 miles in 189 days. Although the waters between Faroe and Faroe Bank are deeper than those which lemon soles normally frequent, it is not considered that they present an insurmountable barrier to migrating fish.

Of the 7 remaining migrants, Nos. 5, 8, 19, 22 and 24 were free for sufficiently long periods as to suggest their arrival at their place of recapture by a route other than the shortest. In other words, they too may have followed the contranatant course. On the other hand, one (No. 7) moved the necessary 30 miles in a southerly direction in 18 days, which indicates that some movement may take place in a direction opposite to the general trend of migration. The last individual

11.

Faroe 1923—1936.

No.	Length cm.	Date	Days Free	Recapture Position	(miles) Approx. Distance Travelled	Area	Sex	Mat.
1	35·4	10. 7.24	54	Off Myling Head	37	WW23b	M.	VI
2	41·0	3. 3.26	655	7½′SExS. Vaagö Hd. .	65	WW22b	F.	
3	37·6	29.12.27	138	12′NW½W. Myling Hd.	44	WW23a	F.	VII-II
4	36·5	11. 2.28	182	14′NW. Myling Hd. ...	46	WW23a	M.	III-IV
5	34·9	9. 4.28	238	62°10′N. 7°22′W.	32	WW23d	F.	
6	40·0	12. 6.31	755	Myggenæs Fjord	54	WW23d	F.	VI-VII
7	25·3	5. 6.29	18	Skuö	30	XX22a	F.	
8	35·5	8. 7.30	416	7′SE. Syderö	50	XX21b	M.	VII
9	36·5	19. 6.32	397	10′NE½N. Kadlar	55	XX24c	F.	IV-V
10	33·7	17. 7.31	58	S.end Faroe Islands	60	XX21a	M.	VI-VII
11	30·2	25.11.31	189	Faroe Bank	60	VV21d	M.	VII-II
12	23·2	2. 7.31	43	Skuö	32	WW22b	M.	VII
13	33·5	22. 5.32	357	Myggenæs	48	WW23c	F.	V
14	38·2	28. 4.34	321	8′SE. Fuglö Head	32	XX23b	F.	V-VII
15	33·5	20.12.34	555	9′NxE. Myggenæs	52	WW23a	F.	II-III
16	35·0	23. 6.34	376	10′NNW. Myggenæs ..	58	WW23c	M.	VI-VII
17	31·2	3. 2.34	235	Myggenæs Fjord	52	WW23d	F.	
18	25·3	17. 6.33	3	6-8′ESE. Fuglö Hd. ..	45	XX23b	F.	III
19	38·2	9. 8.33	56	10′SE. Bordö	55	XX23d	F.	VI-VII
20	20·5	20. 6.33	6	5′NxW. of N. Syderö..	36	WW22d	M.	VII
21	29·4	4. 7.35	24	7′WSW. Sumbö	60	XX21a	F.	IV
22	33·8	20. 6.36	16	Myggenæs	45	WW23c	F.	VII
23	31·2	26. 8.36	83	Fuglö	37	XX23b	M.	VI-VII
24	28·3	1. 9.36	81	Fuglö	40	XX23b	F.	VII

(No. 18) was only at liberty for three days during which it moved approximately 45 miles. This is remarkably rapid movement for a newly-marked fish and accordingly must be taken with caution.

Season of Migration.

For the study of seasonal migration marking experiments are necessary at all times of the year. With such scanty material, therefore, it is impossible to form any opinion. Furthermore, migrants free for short periods alone give satisfactory information for this purpose. From the few short-period migrants recaptured it would appear that migration proceeds during the summer months but it is impossible to say whether it continues in any other season of the year.

Icelandic Markings 1925.

During the visit of the Scottish research vessel to Iceland in June and July of 1925, 375 lemon soles were marked and liberated in five experiments details of which are given in Table 12.

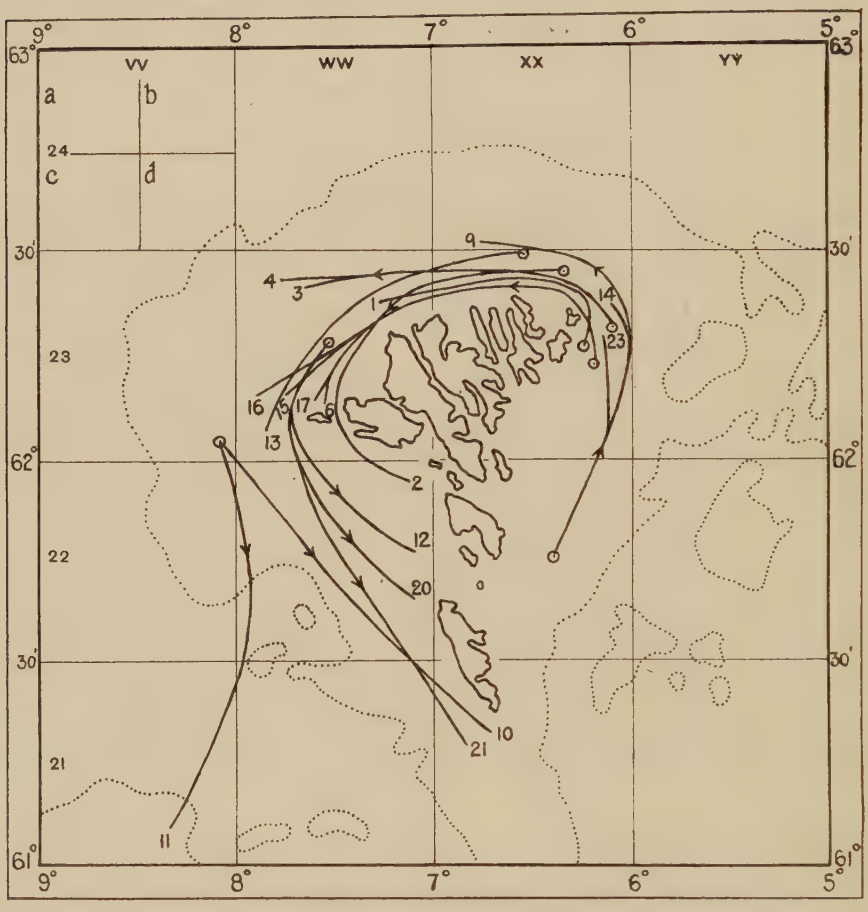

Chart 1. Faroe Islands.
Lemon Sole Migrants, 1923—1936.
Contranatant Movement.

Table 12.

Marking Experiments on Lemon Soles: Iceland 1925.

Experiment No.	Date	Position	Area	Depth (m.)	Number Liber.	Number Recaptured
1	24. June	64°08′N. 22°24′W.	FF27d	35	12	1
2	24. „	64°05½′N. 22°28½′W.	FF27d	36	40	0
3	26. „	63°52′N. 22°49′W.	FF26a	90	128	15
4	27. „	63°34′N. 20°26′W.	HH26d	65	173	11
5	1. July	63°46′N. 16°25′W.	MM26b	63	22	4

Up to 26th April 1928, 31 or 8·3 % were recaptured; since then no recaptures have been made. Twenty-six fish were recaptured by means of the otter trawl, one by seine-net and four by unknown means. The following nationalities contributed to the returns:— England 14, Germany 9, Iceland 5 and Scotland 3.

From the first experiment only one fish was recovered from a position given as south of Iceland, which, though vague, suggests some migratory movement. Out of 128 liberations in the third experiment 15 were recaptured after periods of freedom ranging from 13 to 1035 days. Of these, 5 were free less than 100 days and only three survived for more than a year, two of which, however, were at liberty for about three years. As regards the positions of recapture, two were given vaguely as from Icelandic waters, but all the others were taken within 16 miles of their positions of liberation. From experiment 4 eleven recoveries were made — nine from within 17 miles of their point of liberation and two from unknown positions. Four fish in this experiment survived for more than a year and two of these were free for just over two years. The last experiment near Ingolfs Hofde produced four recaptures after intervals of 14 to 314 days. Two were recaptured on the same grounds and one from a doubtful position. The fourth was recovered from off Skagi at the south entrance to Faxe Bay. If the information regarding this recapture is correct, then the lemon sole must have travelled by the shortest route, approximately 200 miles in 314 days.

An interesting feature is noticeable in connexion with the period of freedom of the marked fish. The following table (13) gives the numbers recaptured within each 100-day period following liberation.

Table 13.

Numbers of Marked Lemon Soles Recaptured per 100-day period. Iceland, 1925.

Days Free	0 100	100 200	200 300	300 400	400 500	500 600	600 700	700 800	800 900	900 1000	1000 1100
Numbers Recaptured	11	1	4	8	1	—	1	3	—	—	2

Of the eleven fish taken within 100 days, ten were recovered within a month. Thereafter recaptures occurred at intervals of one year, e.g., from 300—400 days, 700—800 days and 1000—1100 days. This indicates the seasonal nature of the fishery and the survival of a certain number of marked fish for two or three years.

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Two Years of Sardine Tagging in California.

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Introduction.

A thorough knowledge of the migrations of a fish population which is exploited as intensively as that of the California sardine, *Sardinops caerulea* (Girard), is essential to a practical administration of the fishery. One method of tracing migrations is to tag or mark fish in such a way that individuals may be recognized if caught again. Releasing large numbers of tagged fish with subsequent recovery of the tags will yield valuable information, not only concerning the routes and extent of travel, but will demonstrate whether different regions harbour distinct populations or whether the entire population of all regions is homogeneous. It will show as well whether different portions of the population have different habits of migration, and whether a heavily fished region will be replenished by fish from other localities. Furthermore, if tag recoveries are extensive enough, we can approximate the size of the population and the intensity of fishing — the proportion of the entire population removed each year by fishing operations. When a species is fished over a large area, this information is of additional value in determining the relative fishing intensity in each region. This is the case with the California sardine or pilchard. It is caught for canning and reduction purposes or for bait from British Columbia (Canada) along the entire Pacific coast of the United States to the southern tip of Lower California (Mexico). With the rapid expansion in recent years of the sardine canning and reduction industry has come an urgent need for solving the many perplexing questions concerning the migrations of these fish. This information is essential to the formulation of appropriate regulations for the efficient management of the fishery — a maximum catch consistent with a sustained yield.

Evidence resulting from many years of study of the sardine, made by the State Fisheries Laboratory of the California Division of Fish and Game, points to distinct migrations. Analyses of eighteen years' data pertaining to sizes, maturity, spawning grounds, anatomical characters and other factors indicate that the sardines of the Pacific

coast of North America, from Canada to Mexico, constitute one homogeneous migratory population. These studies have led to the formulation of the following theory: nearly all spawning takes place off southern and Lower California; the young fish remain in these southern waters until adolescent, when they begin northerly migrations, going at first as far as central California and returning the following spring to southern California to spawn; as the fish grow older they go farther and farther north at the close of each spawning season, so that by the time they are eight or ten years old they make annual migrations as far as British Columbia but return to southern waters to spawn.

To corroborate this evidence — or disprove it — and to show the extent of migrations, the California State Fisheries Laboratory, in co-operation with the Biological Board of Canada and the Provincial Fisheries Department of British Columbia, inaugurated a tagging programme. The first sardines were tagged by the British Columbia investigators in the summer of 1935. California workers followed in the spring of 1936. The State of Oregon Fish Commission joined the programme and commenced tagging operations in the summer of 1937. The immediate purpose of the sardine tagging programme is to gain definite knowledge of the movements of these fish throughout their range. However, it may soon be possible to approximate the size of the sardine population by means of tag recoveries, as well as to determine the proportion of the total population removed each year by fishing operations.

Table 1.

Summary of Sardine Tag Recoveries, March 1936—June 1938.

Tagging region	Total number tagged by regions March 1936 to June 1938	Percentage of total tagged	Number of recoveries by regions: Recovered in British Columbia	Recovered in Washington	Recovered in Oregon	Recovered at San Francisco	Recovered at Monterey	Recovered at San Pedro	Recovered at San Diego	Total number recovered
San Francisco-Monterey ..	19,203	35·30	—	—	—	226	138	8	—	372
San Pedro	31,142	57·24	17	5	4	153	77	605	9	870
San Diego	3,007	5·53	4	—	—	20	8	37	5	74
Lower California ..	1,054	1·94	—	—	—	—	—	—	—	—
Broken tags ..			—	—	—	1	2	15	—	18
Totals	54,406	100·00	21	5	4	400	225	665	14	1,334
British Columbia ..	10,449[1])		63	9	9	2	2	6	—	91[1])
Oregon	606[2])		—	—	2	1	—	—	—	3[2])

[1]) Fish tagged by British Columbia authorities. (Hart, 1938.2). Many of these fish were tagged off the coast of Washington.

[2]) Fish tagged by Oregon authorities. Published by permission of the Fish Commission of Oregon.

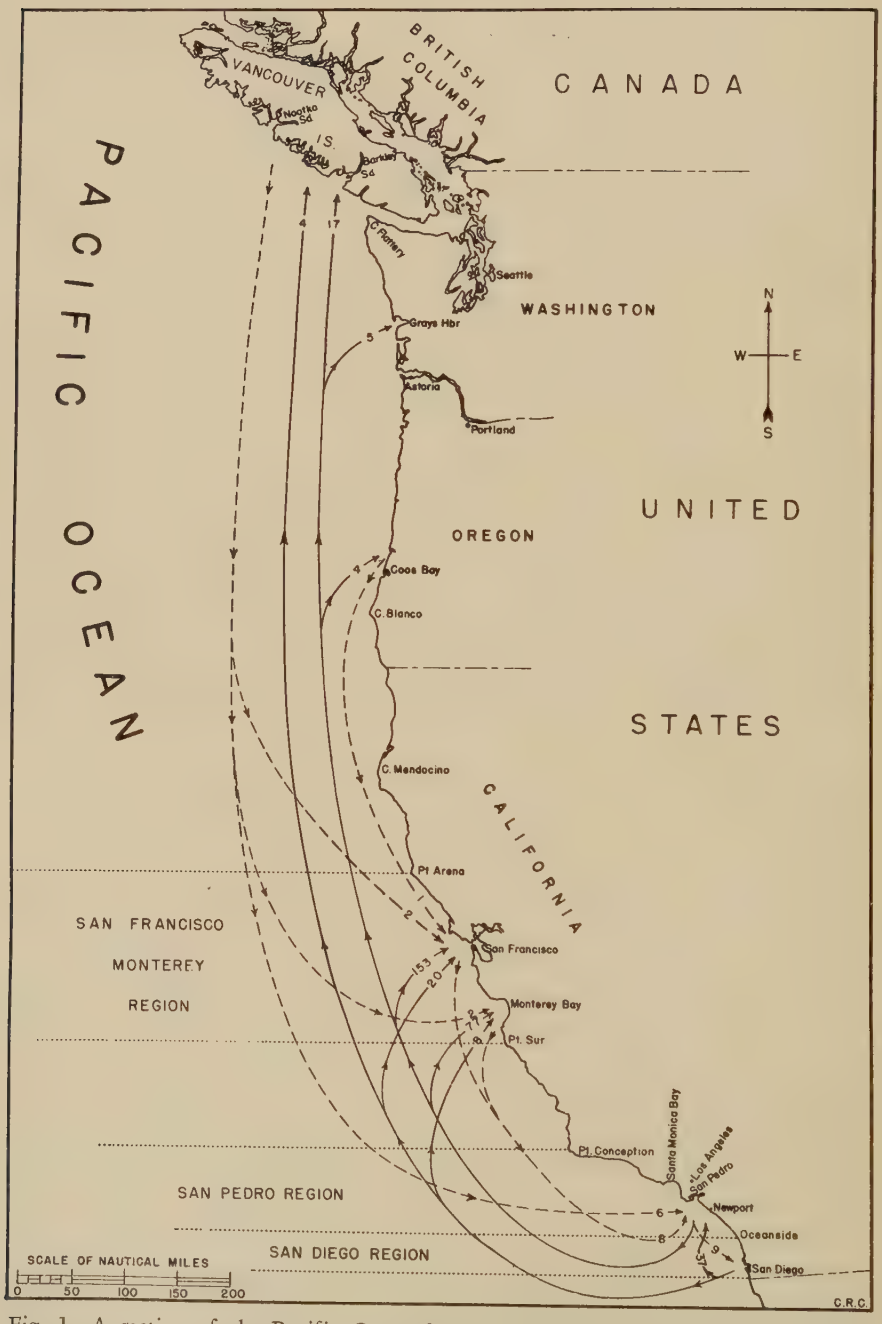

Fig. 1. A section of the Pacific Coast showing diagrammatically major movements of tagged sardines from one fishing region to another, as indicated by recoveries during the period March 1936—June 1938.

It is the purpose of this paper to present only the tagging work which has been performed by the California State Fisheries Laboratory. Summaries of the work done by the Canadian investigators are published elsewhere (H a r t, 1937.1, 1937.2, 1938.1, and 1938.2). From March 1936 to June 1938, the California investigators tagged 53,352 sardines in California waters and 1,054 on the coast of Lower California (Mexico). Already, these tags have yielded 1,334 recoveries along a one-thousand-mile coast line (up to July 1938). All the returns have been in positive accord with the theory of migrations formulated from other phases of the sardine investigation. Since tagged fish were usually released on or near the fishing grounds, most recoveries have been from fish caught soon after tagging in the same fishing region as tagged. However, there has been a decided northward movement of tagged sardines from southern into central California waters. Many of these fish continued north to the coast of Washington where the major part of the 1937 British Columbia catch was made. (See Tables 1 and 2 and Fig. 1.) A southern movement of tagged sardines is also evident. Too few fish have been tagged in Mexican waters to yield any returns. Until recently there have been no means of recovering tags in Mexico so that it has been impossible to trace movements of sardines south of San Diego.

Table 2.

Extent of Migration of Tagged Sardines.

Distance travelled in nautical miles	Number of fish moving	
	North	South
50 or more	325	28
330 or more	288	19
360 or more	58	11
640 or more	30	10
940 or more	26	6
1000	4	0

The Tag.

Internal "belly" tags were first successfully applied to several species of fish by R o b e r t A. N e s b i t of the United States Bureau of Fisheries. Internal tags have been used extensively in the Alaska herring investigation (R o u n s e f e l l and D a h l g r e n, 1933). A tag, closely resembling the herring tag, was adopted for sardine marking on the Pacific coast. External tags or marks generally used for tracing fish migrations would seldom if ever be found because sardines, like herring, are caught and handled in large masses and not as individuals. The California sardine tag is a flat strip of nickel-plated steel[1]), 19·05 × 3·97 × 0·63 mm. All corners and edges are well rounded and smooth. On one side of the tag appears a serial number, sometimes

[1]) The nickel plating must be applied directly to the steel without the usual preliminary copper plating, as copper forms poisonous compounds in the fish.

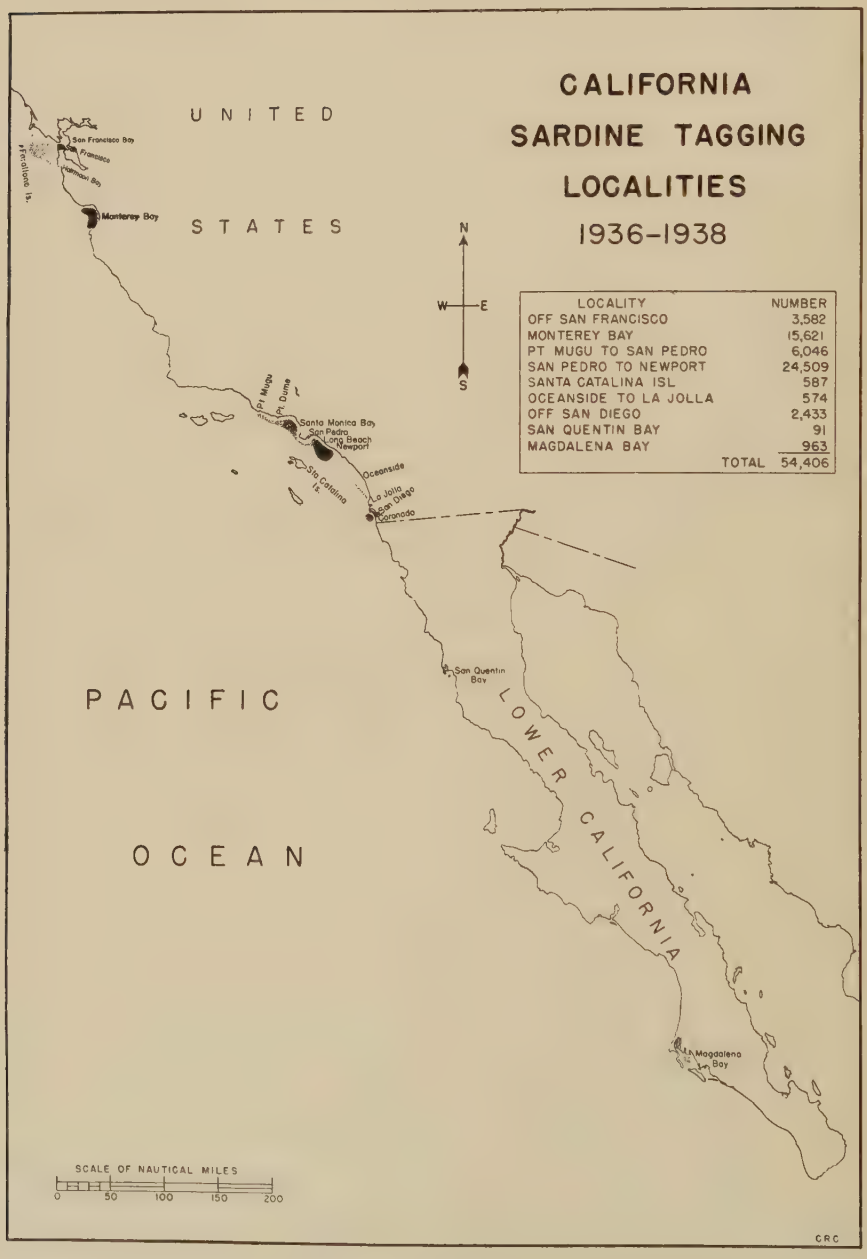

Fig. 2. A section of the Pacific Coast showing the localities where the California Division of Fish and Game has tagged sardines. The number of dots indicates the concentration and range of tagging in each area.

preceded by a letter, and on the opposite side the inscription "CF&G" (for California Fish and Game).

A tag somewhat smaller than the one just described is also in use. It is intended primarily for fish considered too small to be tagged with the larger type. The dimensions of the small tag are 12·70 × 3·17 × 0·63 mm.

Methods of Obtaining and Holding Sardines for Tagging.

Sardines have generally been held for tagging in a live box installed on the after-deck of a fast 14-metre cruiser. This box is 74 cm. deep by 173 cm. long by 71 cm. wide. A small one-cylinder gasoline engine operates a pump which furnishes a constant stream of ocean water. A simple overflow arrangement at one end of the box prevents escape of fish and yet allows the water level to be regulated without decreasing the stream thrown by the pump, thus insuring ample aeration.

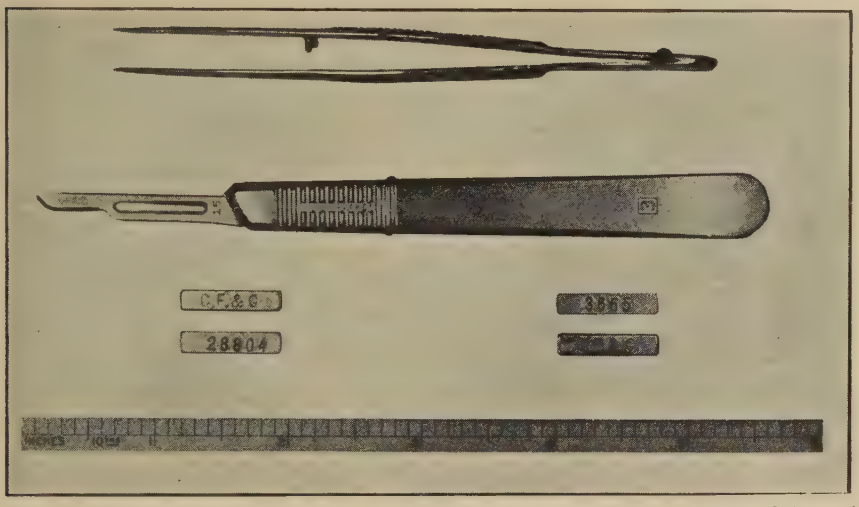

Fig. 3. California sardine tags, the scalpel for making an incision in the fish, and forceps for inserting the tag. Photograph by V. M. Haden, May 1937.

In California waters sardine fishing is usually carried on at night during the dark of the moon, so that most of the tagging work has been done at night. The boat, with tagging crew aboard, cruises to the fishing grounds in search of a fishing boat with sardines in her net. When one is found, and the fishermen are willing to donate a few fish to the cause, the tagging boat draws alongside the big seine skiff and a man with a long handled dip-net boards the skiff. By skilful manoeuvring the boat remains near the seine skiff, and successive scoops of sardines are put immediately into the live box. At night a light is always kept above the fish in the live box. In this way the sardines

soon become accustomed to their new surroundings and are much less nervous than when in total darkness.

By this method, 800 to 1600 sardines can be held at one time, depending upon their size. Tagging usually begins immediately under a flood light placed above the live box. It has been the policy to tag while cruising at sea whenever possible rather than release the fish in harbours. Since the fish are released one at a time as tagged they are distributed over a wide area. The chief advantage of this system is that it gets the fish back into the ocean quickly and consequently in good condition. This appears to overshadow any disadvantage that might arise through failure of individuals to rejoin schools immediately. Transporting sardines to a snug anchorage where tagging can be done more conveniently is frequently time-consuming. Returns are usually better from fish held but a short time. Although tagging is slow when the sea is rough, releasing the fish sooner and consequently in better condition compensates for any disadvantages or inconveniences. On occasions it is possible to lay to on the open ocean but the boat is usually steadier when cruising into or away from the seas. If, as is often the case, the open sea is too rough to make tagging on the fishing grounds feasible, a hasty retreat is made to the nearest shelter, where anchor is dropped.

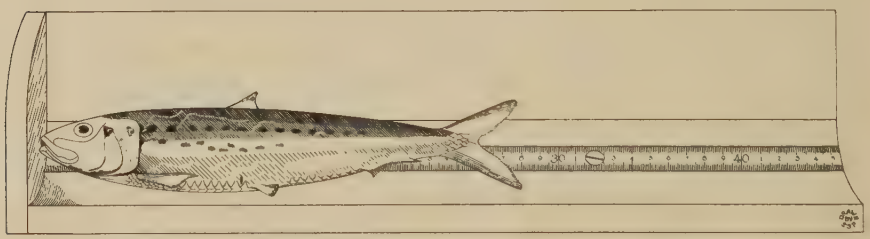

Fig. 4. Drawing of a sardine on the tagging board. The incision through which the tag is inserted is shown slightly anterior to the base of the ventral fin.

Although it is the most successful method yet tried for obtaining large numbers of sardines, the use of a small boat has definite limitations. In the first place, manoeuvring very near a net in rough seas is hazardous, due to the danger of sinking a section of the cork line, which might result in the loss of the fishermen's entire catch. Secondly, approaching a net too closely involves the risk of its becoming fouled in the propellers. In addition, a boat small enough to have the necessary speed and manoeuvrability can carry only a relatively small live box. On the other hand, a fast cruiser, such as has been used in this work, is able to cover a large area in a short time. If fishermen are not finding fish in one locality other districts can be searched the same night, as not all of the fleet from any one port seeks sardines in the same area. Consequently, failures to find fish have been few. Furthermore, when the ocean is too rough to

make tagging at sea practical, only a short time is required to reach shelter, so the fish are not held very long.

The use of radio telephone by sardine fishermen to obtain and spread fishing information makes the use of a short-wave radio receiver a standard item of tagging equipment. By "tuning in on the boats" one can learn where fish are, or are not, being found and set a course accordingly for the most fruitful fishing area.

Fig. 5. Making an incision in a sardine through which a tag will be inserted, and measuring its total length. Photograph by D. H. Fry, Jr., March 1937.

At times it is necessary to rely on live bait and wholesale market fishing boats when the active canning and reduction season is not in progress. These boats are chartered with all or part of their crews and their lampara nets. On such occasions sardines are dipped one at a time from the bag of the net and tagged on the fishing boat. After approximately 400 fish have been tagged, any remaining fish are released and a new set of the net is made. In this way, tagged fish are not seriously scaled or weakened from close confinement. This method eliminates one handling of the fish and results in their being liberated in first class condition.

A live car has been used to hold sardines for tagging but its use was not entirely satisfactory (Janssen, 1937 and 1938.). When it was not necessary to transport the fish to a sheltered anchorage and when tagging could commence immediately on obtaining the fish,

satisfactory recoveries could be expected. However, these ideal conditions can seldom be realized.

Tagging Procedure.

From the outset, it was evident that within practically every batch of fish obtained for tagging, there would be a large range of sizes. As differential migrations of various size-groups have been strongly suspected, it seemed worth while to measure each fish tagged. To

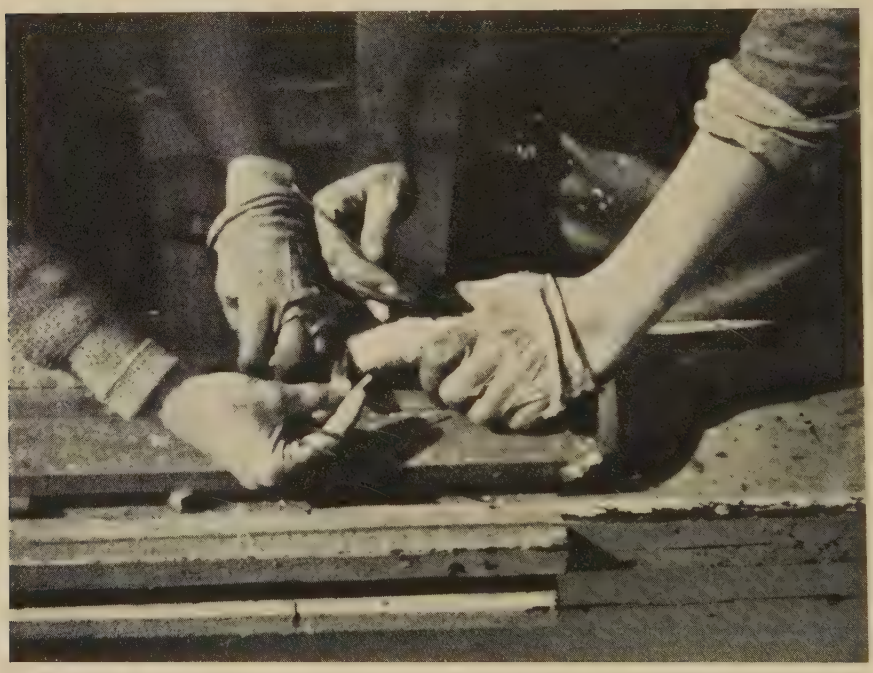

Fig. 6. The tag held in the foreground will be pushed into the incision when the scalpel is removed. Photograph by D. H. Fry, Jr., March 1937.

facilitate both tagging and measuring, a tagging board was constructed with a millimetre rule inlaid in the concave face at a 45° angle, as shown in Figure 4. It is not convenient to measure the standard length of a live sardine so the total length is measured in the tagging work. As tags are sorted in groups of one hundred some way had to be found to handle them conveniently in the field. To serve this purpose a small cabinet was built which holds 24 trays. Each tray has four rows of 25 holes numbered from 0 to 99, inclusive. These holes are about two-thirds as deep as a tag is long. Tags, previously inserted in the appropriate holes, are taken consecutively as used, eliminating the necessity of reading each tag number before putting the tag into the fish. The trays fit close enough to one another in the cabinet so that

the tags cannot fall out of their holes should the cabinet be tipped. A cabinet holds more than enough sorted tags for one night's tagging.

In order to tag the fish as rapidly as possible, two people do the actual tagging, with usually a third person dipping the fish to the taggers and recording the length of each fish on previously prepared sheets of paper. Each sheet has a series of one hundred consecutive numbers identical to the numbers on the tags in the tray in use. Fish

Fig. 7. Pushing a tag into the body cavity of a sardine with a pair of forceps so it will lie between the viscera and body wall. Photograph by D. H. Fry, Jr., March 1937.

slime collecting on smooth hands makes holding a wriggling fish difficult without exerting undue pressure, so the taggers wear thin cotton gloves on their left hands.

With a small dip-net the recorder scoops a sardine from the fish reservoir. One man reaches into the dip-net, grasps a fish around its body at the anterior end and holds it on the concave face of the tagging board with its head against the stop and with its ventral surface facing the operators. While he is making an incision for the tag with a sharp scalpel held in his right hand his partner beside him reads off the sardine's total length. (See Fig. 5.) At the same time the partner picks up a tag from the tray and places it part way within the incision with his right hand, then pushes it into the

abdomen with a pair of forceps (see Figs. 6 and 7) so that it lies between the viscera and body wall. The tagged sardine is immediately dropped overboard.

The position of the incision depends somewhat upon the size of the fish to be tagged. It is slightly above the insertion of the left ventral fin in medium-sized fish, above and a little anterior to the fin in large fish, and above and behind the fin in very small fish.

No attempt has been made to use sterile instruments or tags.

Although the rate of tagging varies considerably under different conditions, a crew of three can tag approximately 300 sardines an hour. In unfavourable situations the rate drops below 200 per hour whereas under very favourable conditions 400 fish have been tagged in an hour.

Sizes of Sardines Tagged.

In discussing sizes of fish tagged it is convenient to divide them arbitrarily into three general groups — large, medium, and small. We regard as small fish those under 200 mm. total length (170 mm. body length). Medium fish range from 200 to 270 mm. and large fish are those over 270 mm. total length (229 mm. body length).

The larger tags have been used for any fish over 180 mm. total length (153 mm. body length), a few reaching 340 mm. in length. The large tags have seldom been used in fish under 180 mm. The small tags are intended primarily for use in fish considered too small to be tagged with the larger type. They are put in any fish above 150 mm. total length (127 mm. body length) and occasionally in fish as small as 135 mm. (115 mm. body length).

Preliminary experiments on tagged fish held in a tank indicate that 135 mm. sardines, or possibly smaller, may be tagged without excessive mortality. However, the smaller sizes lose their scales more easily than larger sardines and consequently suffer considerably more from handling. Further experiments are necessary to definitely determine the size of the smallest fish which may be tagged.

Method of Tag Recovery.

Sardine tags are recovered by means of electro-magnets placed in the meal lines of reduction plants (F r y, 1937). Many whole fish, as well as offal from the canning process, are conveyed to the reduction plants. Briefly the process of reduction is as follows: The fish are run through a press which extracts the oil. The residue is coarsely chopped and run through a drier where it crumbles into small pieces. This mass then passes over a magnet before going into a grinder for final sizing. Bits of metal, including tags, are retained on the magnet. By this means, the tag only and not the fish is recovered.

In so far as funds have allowed, magnets have been placed in all reduction plants where their installation is mechanically possible. In California, magnets are supplied by the California Division of Fish

and Game and installed by the reduction plants, except in the case of a few plants which operate private magnets to keep metal scrap out of their grinders. The magnets pick up unbelievable quantities of metal such as nails, bolts, fish hooks and broken pieces of machinery, which somehow find their way into the reduction pit. Consequently careful sorting is necessary to find all the tags which may have collected on a magnet.

Although we can trace movements of tagged fish from one region to another we cannot follow their movements within a region. Fish from many boats are often unloaded into one reduction pit, so that it is impossible to determine from which boat a tag may have come. Consequently it is not possible to tell in which locality within a fishing region the fish bearing the tag may have been caught. To meet this problem in its Alaska herring investigation, the U.S. Bureau of Fisheries has devised an electronic detector (Dahlgren, 1936). This instrument makes possible the recovery of the fish bearing the tag at the time that a boat is being unloaded, and as a result the locality in which the fish was caught can be ascertained. The cost of installing and operating these detectors prohibits their use in the many California plants.

Tag Loss.

Tag loss may be considered as the loss of tags by any means whereby they cannot later be recovered. Many fish must die from the effects of being tagged, and some of the survivors shed their tags. Experiments are now under way to determine the tagging mortality and the loss due to shedding of the tags. Aside from the fact that not all reduction plants are equipped with magnets to recover tags a sizable portion of the sardine catch is used for bait from which there is no chance of tag recovery. Predators are known to account for some tagged fish while they are still in a weak condition, and this loss is probably quite considerable at times. The efficiency of different magnets varies significantly due to a variety of causes. Tests are being made to determine the efficiency of the recovery system in the reduction plants. A careful evaluation of tag loss and especially its variability is fundamental if a measure of fishing intensity is to be obtained from tag recoveries.

Mechanical Tabulation of Tag Recoveries.

An analysis of tag returns obviously necessitates the tabulation of recoveries in a number of different ways. As returns become more numerous (over 1,300 at the present writing) the task of organizing the data becomes increasingly involved. This task has been simplified by the use of the California Division of Fish and Game Hollerith electrical statistical equipment (Conner, 1935) to record tag recoveries on punch cards. Each card has 45 vertical columns of consecutive numbers from 0 to 9. (See Fig. 8.) All pertinent

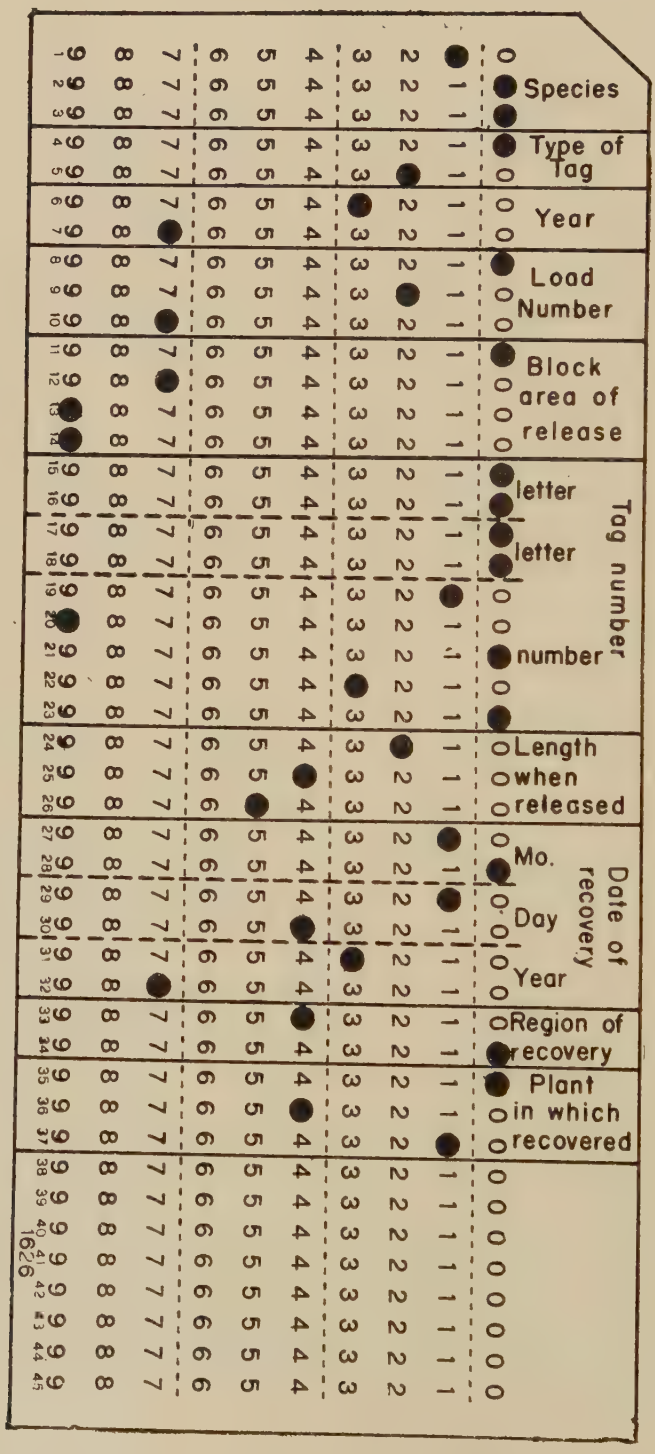

Fig. 8. Facsimile of punched card used in tabulating sardine tag recoveries.

information relating to each recovered tag is coded into numbers. The system is quite flexible so the method may be applied to any species of fish which may be tagged. Space is provided on each card for coding additional information which may be found useful in the future, but has not seemed important at the present time. An electric key-punch is used to transfer the code to the card by punching out the code numbers.

A sorting machine arranges the cards in any desired order or separates any group or individual card from the rest. A mechanical tabulator automatically combines and summarizes any desired information appearing on the sorted cards and presents the data in printed form.

Tagging and Recovery by Regions.

San Francisco—Monterey Region.

As shown in Table 1 there have been 372 recoveries from the 19,203 sardines tagged in the San Francisco-Monterey region. Of these, 10,981 were tagged during the 1937—1938 season, yielding 350 of the recoveries. This is a vast improvement over the previous year, largely due to better methods of holding the fish. Although 258 tags have been recovered in central California from fish released in southern California, only eight central California tags have been recovered in the south. This is a satisfactory recovery in view of the fact that relatively few fish were tagged in central California waters compared with the number tagged in the south. In addition most of the sardines released between San Francisco and Monterey have been tagged early in the season and consequently were subjected to an intensive fishery over a period of several months. The tagged fish-stock left to move south was therefore quite small.

San Pedro Region.

The 31,142 sardines tagged in the San Pedro region have yielded 870 returns. Many of these fish were released since the close of the past canning and reduction season so there will be no opportunity for recoveries until the 1938—1939 season commences.

Sardines released in the San Pedro region have been recovered in all the major sardine fishing localities on the Pacific coast. The plants on Vancouver Island, British Columbia, have accounted for 17 tags from this region; Washington, 5; Oregon, 4; San Francisco, 153; Monterey, 77; and San Diego, 9. (See Table 1.)

San Diego Region.

There have been 3,007 sardines tagged in the San Diego region. From these there have been 74 returns. Four of the tags released in this region in the spring of 1937 were recovered in British Columbia the following summer; and during the 1937—1938 season in California, 20 of these tags appeared at San Francisco, 8 at Monterey and 4 at San Pedro.

Lower California.

No means were provided until recently for the recovery of sardine tags in Mexico. There is a small sardine fishery out of the port of Ensenada and two plants have installed magnets. However, so few fish are reduced that at best few tags may be expected from that

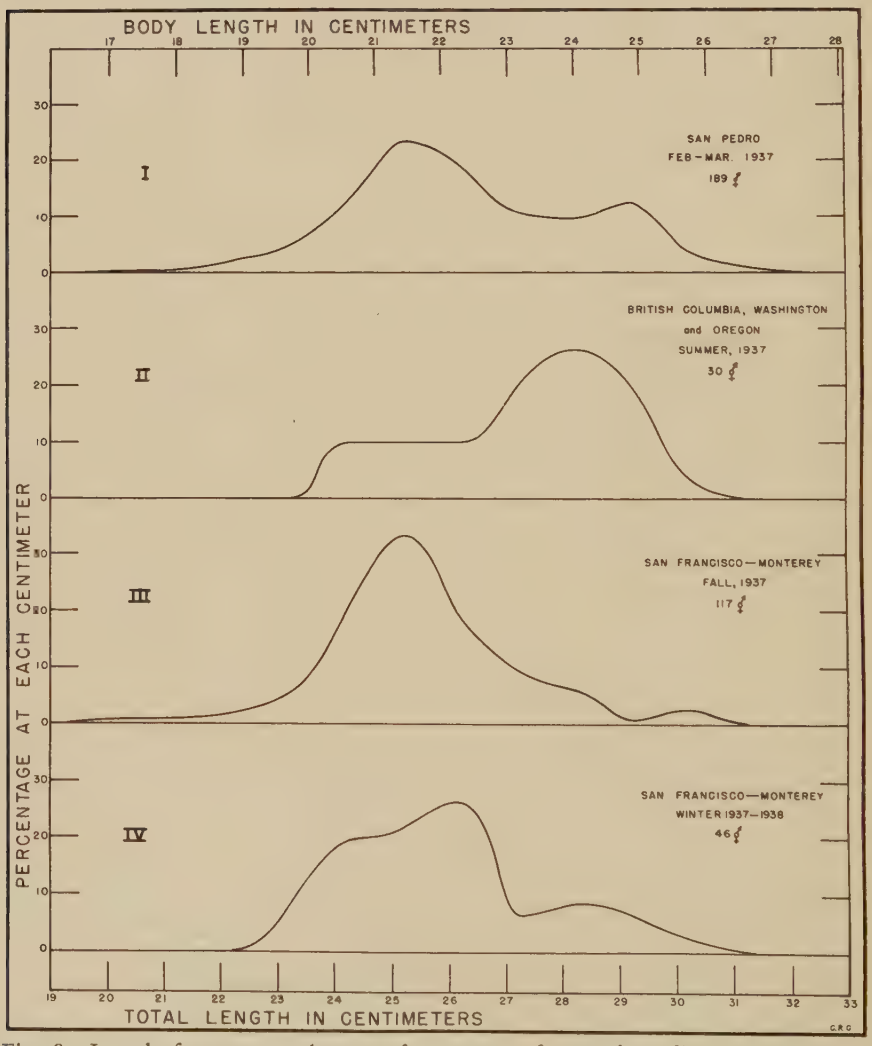

Fig. 9. Length frequency polygons of a group of tagged sardines recovered at different localities along the Pacific coast. The fish were all tagged and released in southern California waters, January—March 1937. The lengths given are the sizes at time of tagging, not at time of recovery. Frequency I shows the sizes of fish recovered at San Pedro within a few weeks after tagging; frequency II, fish recovered in British Columbia, Washington, and Oregon in the summer of 1937; frequency III, recoveries at San Francisco and Monterey in the fall of 1937; and frequency IV, recoveries at San Francisco and Monterey in the winter of 1937—1938.

source. There is a good sized bait fishery along the coast of Lower California which unquestionably takes many of the small fish tagged in that territory. Unfortunately no recoveries can be obtained from fish used as bait.

In April 1938, 963 sardines were tagged in Magdalena Bay, about 580 miles south-east of San Diego. This is the southernmost locality in which sardines have been tagged.

Differential Movements of Medium and Large-Sized Sardines.

From the sardines tagged off southern California during the late winter and early spring of 1937, there have been recoveries in all the major sardine fishing areas on the Pacific coast. Since there was a wide range of sizes tagged during this period, data on these fish were analysed to determine whether the larger tagged fish made longer migrations than the smaller and medium sizes. From the recovery data, four frequency polygons were made of the lengths of the fish recovered in different areas. (See Fig. 9.) Since it is impossible to determine the length of tagged sardines at the time they are recovered, the total lengths of each fish at the time of tagging were used. To obviate the necessity of a correction for growth, only recoveries obtained over a limited period of time were considered. Frequency polygon I includes all fish caught soon after tagging in the same fishing region as tagged. This curve should represent a cross-section of the survivals from the late winter and early spring tagging in southern California in 1937. The next frequency, II, includes the tagged sardines recovered in British Columbia, Washington and Oregon, in the summer of 1937 from this same southern California tagging. Frequency III represents recoveries of these southern tagged fish taken in the fall of 1937 at San Francisco and Monterey, and the last curve, IV, includes the recoveries in this same region during the winter of 1937—1938.

If all of these fish, irrespective of size, had the same habits of migration, the frequency polygons should obviously be quite similar. Since they are apparently different, a reliability test was applied to aid in the proper interpretation of their differences. χ^2 gives a satisfactory measure of the probability that two frequencies are samples of the same population if each frequency is composed of over 100 individuals. The *t* test may be applied if small numbers are involved in each frequency. Since we are comparing frequencies containing both small and large numbers, both the χ^2 and *t* tests were applied to all frequencies. (Pearson, 1914, p. 92; Yule and Kendall, 1937, p. 442; and Treloar, 1935, appendix, Table 3).

Table 3.

A Comparison of the χ^2 and *t* Tests Applied to the Four Frequencies.

	I and II	I and III	I and IV	II and III	II and IV	III and IV
P from χ^2	0·03043	0·00497	0·39737	<0·000015	<0·000015	0·30935
2τ from *t*	0·00677	0·00036	0·18625	<0.0000002	<0·00019	0·20690

From the four frequencies there are six possible comparisons. Table 3 shows a comparison of the values obtained by the two methods. If our theories of sardine migrations are correct, we should not expect small tagged fish to move from southern California into British Columbia, Washington and Oregon waters within a short time interval. Furthermore, the large sizes should dominate the medium sizes in the north. A comparison of frequencies I and II bears out this contention but the number of individuals in frequency II are too few to make the curve very reliable. However, the *t* test indicates that the differences are significant.

Comparisons of curve II with III and II with IV indicate that during the summer the bulk of the large tagged fish from southern California were in regions north of the San Francisco-Monterey fishing grounds. The differences between these curves are highly significant. On the other hand, if the smaller tagged fish have not moved as far north as the British Columbia, Washington and Oregon fishing grounds they should be taken in the San Francisco-Monterey fall fishery. This is clearly indicated by the comparisons of curves I with III and II with III and the tests of reliability for these comparisons.

According to present theories of sardine migration the large fish from the north are expected to arrive in numbers off central California during the winter. These fish are thought to continue to southern California waters with the medium-sized fish. We might expect then that the sizes of fish taken in the winter months at San Francisco-Monterey and San Pedro should be very similar. This is indicated by the similarities of frequencies I and IV and by the measures of reliability.

For the comparisons between the San Francisco-Monterey fall and winter frequencies, curves III and IV, the winter frequency should contain more large fish than does the fall frequency. This is true, but the measures of reliability indicate that the differences are not significant.

Acknowledgements.

The State Fisheries Laboratory of the California Division of Fish and Game is indebted to the Bureau of Patrol of the Division for their willing co-operation in making available to us their patrol boats, and to the boat crews for their valuable assistance. We are grateful to the many fishermen who have donated sardines for tagging purposes, and to those owners and employees of canneries and reduction plants who have co-operated in the recovery of the tags. We appreciate the co-operation extended by the officials in British Columbia, Washington and Oregon who have exchanged tagging data with us and arranged for the recovery of California tags in their localities.

Zusammenfassung.

Die Wanderung der Kalifornischen Sardine, *Sardinops caerulea* (Girard), an der Pazifischen Küste von Nord-Amerika wird gemeinsam von den Staaten Kalifornien, Oregon, Washington, der Provinz Britisch Columbia und der Dominion von Canada beobachtet und studiert. Dieser Artikel bezieht sich vornehmlich auf die Erfahrungen des Staates Kalifornien.

Von März 1936 bis Juni 1938 wurden in den Gewässern an der Küste Kaliforniens 53,352 Sardinen und an der angrenzenden Mexikanischen Küste 1054 Sardinen mit einer kleinen Stahlmarke gezeichnet und von diesen sind bereits 1334 eingebracht worden. Da die gezeichneten Fische meistens in der Nähe des Fischereigebiets befreit wurden, kamen von hier bei weitem die grösste Anzahl der Marken zurück. Aber 258 Marken von den in Süd Kalifornien gezeichneten Fischen wurden in Zentral Kalifornien gefangen, einer Entfernung von ungefähr 460 Kilometer, und 30 von Oregon, Washington und Britisch Columbia, also 1100—1850 Kilometer vom Ausgangspunkt. Umgekehrt wurden 10 Marken von Fischen, in Britisch Columbia gezeichnet, in Kalifornien eingebracht, welche also ebenfalls eine Reise von etwa 1300—1850 Kilometer zurückgelegt hatten.

Eine innere Marke wird zu diesem Zwecke verwandt und zwar ein flacher vernickelter Stahlstreifen 19·05 × 3·97 × 0·63 Millimeter mit einer laufenden Nummer, welche in die Bauchhöhle des Fisches eingesetzt wird.

Die Marken werden meistens zurückgewonnen durch einen Magneten, der in den verschiedenen Fischverarbeitungsfabriken aufgestellt ist.

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The Selective Action of the Drift-Net on the Cornish Pilchard.

By

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IN September 1938, the Ministry of Agriculture and Fisheries' research drifter "Onaway" made a series of experimental hauls with a fleet of drift-nets in the pilchard fishery of the Mounts Bay region of Cornwall. The fleet consisted of ten nets, each net being 100 yards long by 10 score deep, fitted, as in the commercial pilchard drift-net, with 20 foot strops. Three of the nets had meshes of a size 36 rows to the yard, three of 42 rows to the yard, two of 46 rows to the yard, and two of 52 rows to the yard.

The experiments had two main objects. Firstly, they were an attempt to find whether any small pilchards or sardines were present in the vicinity of the regular pilchard fishery. Secondly, they were carried out with a view to obtaining data to show how the selective action of the drift-net may affect estimates of the rate of growth of the pilchard, and so render easier a comparison of the Cornish pilchard with the French sardine, which is captured with drift-nets of very small mesh.

Five successful hauls were made at the positions shown in Figure 1. Three of the shots were in Mounts Bay; one was to the west of Mounts Bay between Lamorna Cove and the Runnelstone Buoy, and one was out to sea south-east of the Wolf Rock Lighthouse. At two of the stations it was impossible to handle all the fish caught, and an aliquot sample only was measured, and raised to the estimated total catch. At the other three stations all the fish were measured.

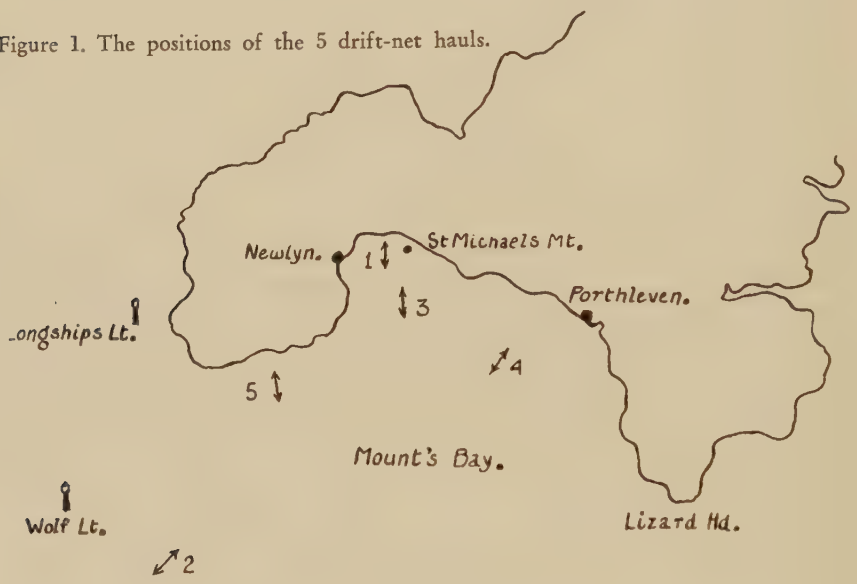
From the hauls at each station about 100 fish were taken, distributed between the nets of different mesh. These fish were examined for the determination of the sex and weight, and a scale was taken from each for age and growth estimations.

The estimated total catch of pilchards varied greatly from station to station. The smallest shot yielded 106 fish, the largest, 1,706 fish,

indicating a "patchiness" of the shoals of pilchards entirely typical of pelagic fish. In the present paper, however, the five shots are not treated separately, but are combined, and in this form they probably present a good picture of the state of the pilchard stock in the Mounts Bay region at the time of the experiments.

It is a pleasure to acknowledge my gratitude to Mr. G. A. Steven, of the Plymouth Laboratory, for his help in the collection of these data both at sea and ashore.

Figure 1. The positions of the 5 drift-net hauls.



Length.

In Figure 2 (top curve) is shown the percentage distribution at each centimetre length of samples of the pilchards taken at all stations and by all nets. The range in length was from 17 to 25 cm., and the curve was trimodal, with modes at 18, 21, and 23 cm. The dotted curve in the graph shows the distribution of the males; it is clear that, at lengths of 21 cm. and less, males greatly predominated over the females in the catches. In the whole series of experiments males formed 62 per cent. of the pilchards caught. None of the fish taken, whether males or females, was immature; all had either spawned, or were about to spawn for the first time (stages II upwards).

The remaining four curves in Figure 2 show the percentage distribution at each centimetre length of the pilchards taken by the nets of mesh 52, 46, 42, and 36 rows to the yard respectively.

The numbers of fish taken by each net varied greatly. The net of smallest mesh, namely, 52 rows to the yard, took only 55 fish in all

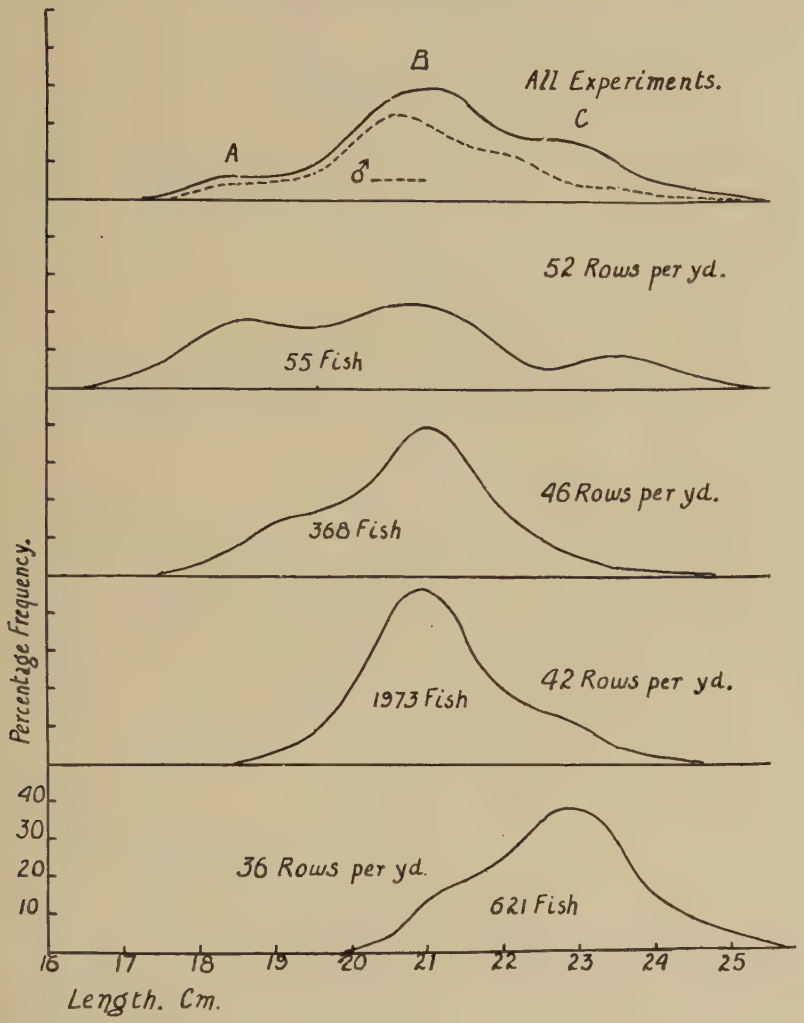


Figure 2. The percentage frequency distribution of the pilchards caught. Length.

the experiments; that of 46 rows to the yard took 368 fish; that of 42 rows to the yard took 1,973 fish; and that of 36 rows to the yard took 621 fish. The net of 42 rows to the yard was consistently, in every shot, the most productive, and did far better than the net of 36 rows to the yard. This point is interesting, because the drift-nets used by the commercial pilchard boats are about 36 rows to the yard when new; but after long use they probably shrink to a size of about 37 to 39 rows to the yard.

The curves in Figure 2 show that the mesh of the net has a very marked effect on the size of pilchard caught. If the three modes in the top curve in Figure 2 are named, from the smallest to the largest,

A, B, and C, it will be seen that the largest mesh used, that of 36 rows to the yard, took mainly fish belonging to group C at about 23 cm. The net of 42 rows to the yard took mainly fish belonging to group B, with some of group C. The net of 46 rows to the yard also took fish mainly belonging to group B, but also many of group A. Finally, the very few fish taken by the net of 52 rows to the yard consisted about equally of fish in groups A and B, and also many of group C. These larger fish, however, were all taken "by the nose" and not truly gilled.

The average length of the pilchards taken by the four meshes was as follows:— 36 rows to the yard, 22·8 cm.; 42 rows to the yard, 21·1 cm.; 46 rows to the yard, 20·7 cm.; 52 rows to the yard, 20·5 cm.

These results are very similar to those obtained by Hodgson (1) in his experiments with drift-nets of different mesh in the herring fishery, and show that in the pilchard, as in the herring, drift-nets of different mesh will select fish rather sharply from the pilchard shoals present.

If one were using these samples to examine the length composition of the pilchard shoals in the Mounts Bay region, a very different picture would be presented by the use of the sample collected by the nets having a mesh of 42 rows to the yard, say, as compared with that collected by the nets of 36 rows to the yard. This is of some importance, because, owing to the unprosperous state of the pilchard fishery, we may be sure that new nets are bought as seldom as possible, and used as long as possible, so that commercial samples of pilchards may vary considerably in their length composition simply because they have been caught by nets of different ages, some of which may have shrunk to a comparatively small size.

Owing to the distribution of the sexes shown in the top curve in Figure 2, the selective action of the drift-net will also affect the proportion of males and females in the samples. The small-meshed nets should show an excess of males, and this is, in fact, found to be the case. The net having 46 rows to the yard gave a sample containing no less than 75 per cent. of males; that having 42 rows to the yard, 60 per cent.; and that having 36 rows to the yard, 48 per cent. of males. This finding illustrates the difficulty of using drift-net samples to estimate the sex-ratio.

The selective effect of the drift-net is well known in Brittany, where the sardine fishermen use nets of a very wide range of mesh-size, according to the size of the sardines sought. Le Gall (2) has shown the relation between the size of the mesh used and the average size of the sardines caught, and in order to compare his results with mine I have converted his data from his unit of the "moule" of the net, to the English unit of "rows per yard". His results are shown in my Figure 3, where the crosses represent his data. The relation between the size of the mesh and the average length of the sardines caught is a linear one, and I have drawn a line through them representing this relation.

In Figure 3 I have inserted the results of the present experiments

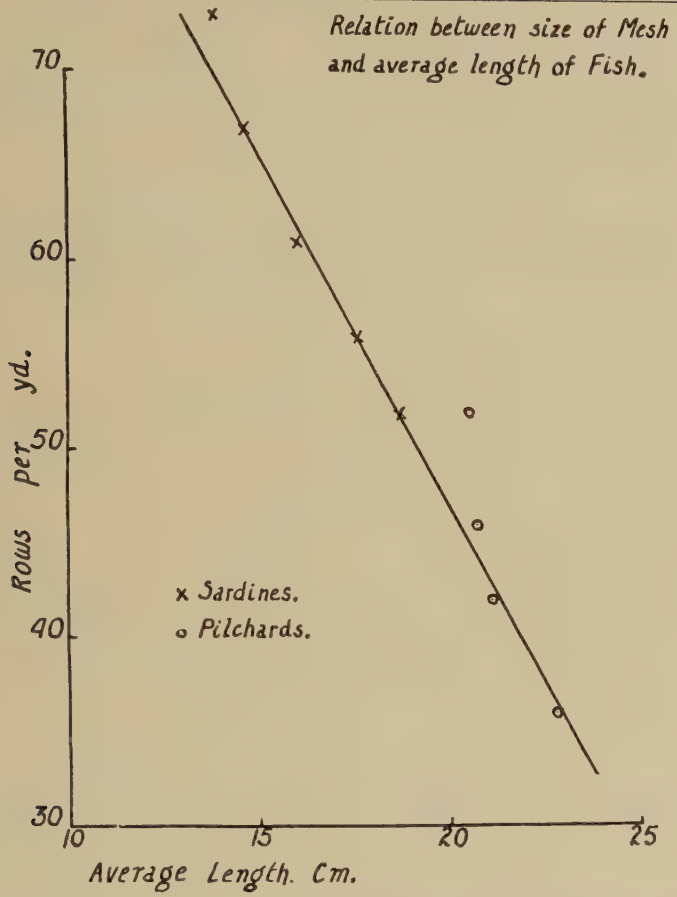


Figure 3. The relation between the size of the mesh and the average length of the pilchards caught.

as circles. The average length of the pilchards taken by the nets of 36 and 42 rows to the yard fall very satisfactorily on the straight line extrapolated from le Gall's data. On the other hand, the average length of the pilchards taken by the nets of 46, and to a much more marked degree by the net of 52, rows to the yard diverge from this line. The pilchards taken by these nets were larger than they should have been; by comparison with the French data, as Figure 3 shows, the net of 52 rows to the yard should have caught pilchards of an average size of about 18·5 cm., instead of the 20·5 cm. actually found. The capture of large pilchards, held "by the nose" in the small meshes, will partly account for the discrepancy, but the chief explanation would seem to be that small pilchards of sardine size were not present in the pilchard shoals in the Mounts Bay fishery, at least at the time of the experiments. This is confirmed by the fact that the range of length of the pilchards taken by the smallest mesh was

the same as that of pilchards taken by the much larger mesh of 42 rows to the yard; and by the scanty number of pilchards taken by this small mesh, though it is effective in Brittany, where sardines are abundant.

Weight.

In Figure 4 is shown the percentage distribution at each 10-gramme group of the pilchards captured by the mesh of 46, 42, and 36 rows per yard respectively. The mesh of 46 rows to the yard gave a curve

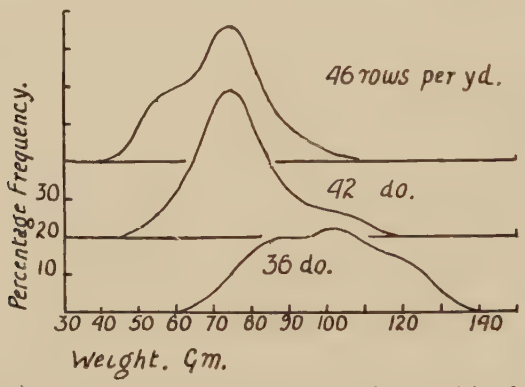


Figure 4. The percentage frequency distribution of the pilchards caught. Weight.

having a mode at about 75 gm., with the suggestion of a mode at about 55 gm. The fish taken by the mesh of 42 rows to the yard also showed a mode at about 75 gm., with the suggestion of a mode at about 100 gm. Finally, the fish taken by the mesh of 36 rows to the yard showed a mode at about 100 gm.

The average weight of the pilchards taken by the mesh of 46 rows to the yard was 73 gm.; by the mesh of 42 rows to the yard, 78 gm.; and by the mesh of 36 rows to the yard, 101 gm.

These results also are in harmony with le Gall's. He gives the average number of sardines per kg. corresponding to each "moule" of the sardine drift-nets used in Brittany, and when these are converted into units of "rows per yard" it is found that the curve produced by these data, when extrapolated, passes through the points representing the average number of pilchards per kg. at each size of mesh used in the present experiments. One may say, therefore, that in terms of the French unit the nets used in these experiments were of "moule" 100 (for the net of 36 rows per yard), 87—88 for the net of 42 rows to the yard, and 80 for the net of 46 rows to the yard. The nets actually in use in the commercial pilchard fishery would have a "moule" of about 95—100.

Experiments not yet published have shown that, at all seasons of the year except in late autumn and winter, the larger pilchards are, on

an average, in poorer condition than the smaller pilchards. Therefore it might be thought that the condition of the pilchards caught by the smaller-meshed nets would be better than that of pilchards caught by the larger-meshed nets, an important matter from the commercial point of view. But the results of the present experiments do not confirm this. The average "condition" of the pilchards caught by the small-meshed nets, as judged both by the length-weight relation and by the amount of intestinal fat present, was not superior to that of the large-meshed nets.

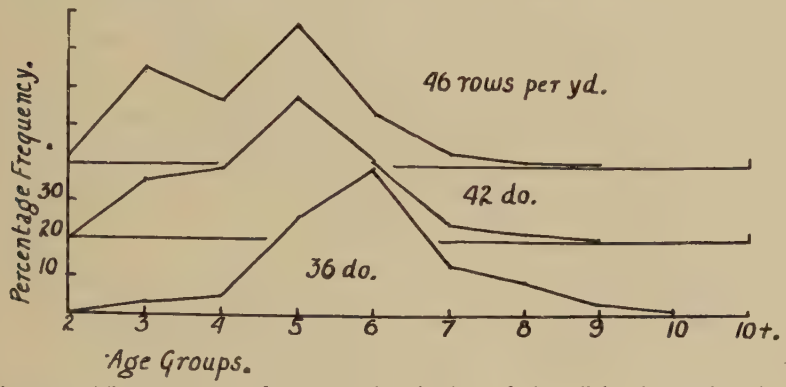


Figure 5. The percentage frequency distribution of the pilchards caught. Age.

The discrepancy may probably be explained by reference to Farran's (3) paper "On the mesh of herring drift-nets in relation to the condition factor of the fish". He there pointed out that a herring in poor condition has a narrower maximum girth, and also a narrower girth just behind the gill cover, than a herring in good condition. From the point of view of liability to entanglement in the meshes of a drift-net therefore, a larger herring in poor condition is equivalent to a smaller herring which is in good condition, and therefore thick in the body.

In the present experiments, the small meshes took the small fish in good condition, but also the large fish in poor condition, whereas the larger mesh took the large fish in good condition, the two factors about balancing each other.

Age.

In Figure 5 are shown three polygons representing the percentage age-distribution of the pilchards caught by the nets having a mesh of 46, 42, and 36 rows to the yard respectively. The largest mesh caught chiefly six-year-old fish, and also many fish 5 and 7 years old. The mesh of 42 rows to the yard, on the other hand, caught mainly fish of 5 years old and also many fish 3, 4, and 6 years old. Finally the smallest mesh of 46 rows to the yard caught mainly two year-classes, the three- and five-year-old.

The effect of selection is here very striking. The catch of the smallest-meshed nets gives a totally different impression of the age-composition of the stock of pilchards from the catch of the largest-meshed net, though both samples were in fact drawn from the same population.

This result shows how great is the need for caution in estimating the age-composition of a stock of pilchards or sardines from commercial samples, for pilchards have been caught in nets which may vary substantially in the size of their mesh, especially among the older nets, and sardines are caught by nets having a very wide range of mesh-size.

The Effect on the Apparent Rate of Growth.

Since the selective action of the drift-net affects both the length and the age of the pilchards caught, it follows that the average length of the fish belonging to each age-group should also be affected. This is the case, as may be seen in Table I below.

Table I.

Average Length of the Age-Groups.

Mesh	"Moule"	3	4	5	6	7	8
46	**80**	19·0	20·3	21·0	21·3	22·1	—
42	**87—88**	19·7	20·5	21·1	21·7	22·8	22·6
36	**100**	20·6	21·4	21·9	22·4	23·5	23·9

The average lengths of the age-groups are a centimetre or more greater in the samples taken by the large-meshed net of 36 rows to the yard, as compared with those taken by the small-meshed net of 46 rows to the yard, and if it were not known that both samples had been drawn from the same stock it might be concluded that there was a substantial difference in the average rate of growth of the fish in the two samples.

The effect of net selection extends further than this: it even affects the average length of the fish at the end of each growing period of its life, as calculated from the spacing of the annual rings of growth on the scale. In Table II below are given the average calculated lengths of the fish, at the time of formation of the first, second, and later annual rings (l_1, l_2, etc.), in the samples taken by the mesh of 46, 42, and 36 rows to the yard respectively.

In the table, two opposite tendencies may be seen. Firstly, the calculated average length of the fish at the time of formation of each annual ring decreases with the increasing age of the fish. For example, among the pilchards taken by the mesh of 42 rows to the yard ("moule" 87—88) the average length of l_1 increases from 7·2 cm., as calculated from the 6-year-old fish, to 9·6 cm. as calculated from the 3-year-old fish. (The few two-year-old fish taken in these experiments had a very high value for l_1, namely, 14·3 cm.) This phenomenon is well known, especially perhaps among clupeoids; it has been called

Table II.

Average Rate of Growth as calculated from the Scales.

Mesh	"Moule"	Calculated from the	Average value of l_1	l_2	l_3	l_4	l_5
46	**80**	3-year-old fish.	8·7	16·1	—	—	—
		4- „ „ „	9·1	15·7	18·8	—	—
		5- „ „ „	7·6	14·5	18·4	20·0	—
		6- „ „ „	7·7	14·1	18·0	19·7	20·5
		All the fish.	8·3	15·1	18·4	19·8	20·8
42	**87—88**	3-year-old fish.	9·6	17·1	—	—	—
		4- „ „ „	9·1	15·8	18·8	—	—
		5- „ „ „	7·8	14·6	18·4	20·0	—
		6- „ „ „	7·2	14·1	18·2	20·1	21·1
		All the fish.	8·2	15·1	18·4	20·1	21·1
36	**100**	3-year-old fish.	9·4	18·2	—	—	—
		4- „ „ „	9·8	15·5	19·8	—	—
		5- „ „ „	8·5	16·0	19·6	20·9	—
		6- „ „ „	8·0	15·0	19·0	20·8	21·6
		All the fish.	8·5	15·5	19·2	20·9	21·9

"Lee's phenomenon", and it has recently been discussed by Robertson (4) as it occurs in the sprat. In the present paper no attempt will be made to explain it further; it may clearly be seen in the data published by Fage (5) on the calculated rate of growth of the pilchard and sardine, and Desbrosses (9) gives figures which show that, in two samples of sardines, the average value of l_1 is greater in the younger than in the older fish, though he attributes the difference to an annual variation in the rate of growth.

It is probable that "Lee's phenomenon" accounts for the discrepancy between the observed length of the age-groups given in Table I and the calculated lengths given in Table II. For example, the average length of the 4-year-old fish is given, in Table I, as 20·3, 20·5, and 21·4 cm. according to the mesh used, whereas, in Table II, the calculated values of l_4 are respectively 19·8, 20·0, and 20·8 cm. But the calculated values of l_4 have necessarily been worked out from 5-year-old fish, the observed values, of course, from 4-year-old fish.

Secondly, when the effect of "Lee's phenomenon" is avoided by calculating the average values of l_1, l_2, etc., from fish of the same age taken by the nets of 46, 42, and 36 rows to the yard, the effect of net selection is clearly to be seen.

Again, taking an example from Table II, the average values of l_1 to l_4, calculated from the 5-year-old fish (the most frequent age in the whole series of samples), are as follows:—

Mesh	"Moule"	Value of	l_1	l_2	l_3	l_4
46	**80**		7·6	14·5	18·4	19·9
42	**87—88**		7·8	14·6	18·4	20·0
36	**100**		8·4	15·7	19·6	20·9

The larger mesh, in selecting, as compared with the smaller mesh, not only the larger fish, but the larger fish of each age, has affected the calculated rate of growth. For it is known that a well-grown fish tends to have been well grown throughout its life, and since the larger and better-grown members of each age-group have been selected by the larger mesh, the calculated rate of growth of these fish must be higher than that of the fish selected by the smaller mesh.

In Table II the average values of l_1, l_2, etc. calculated from all the fish examined from the catches of each mesh are compared. It appears that there is little difference in the values of l_1, but that a difference becomes increasingly marked among the values of l_2, l_3, l_4, and l_5. One important reason for this is that the two factors described above, namely, "L e e's phenomenon" and the selective action of the meshes, tend to neutralize each other. The mesh of 36 rows to the yard gives higher values for l_1 at each age-group than that of 46 rows to the yard; but, on the other hand, the values for l_1 for all the fish taken by the mesh of 36 rows to the yard are calculated namely from 5-, 6-, and 7-year-old fish (Figure 5) whereas those for the mesh of 46 rows to the yard are calculated mainly from fish 3, 4, and 5 years old. Owing to "L e e's phenomenon", the latter give higher average values for l_1 than the former, and thus tend to balance, in the final average, the superior values of l_1 in the former due to net selection. But among the values of l_3, l_4, and l_5, "L e e's phenomenon" is less marked and the selective action of the net prevails, giving increasingly large average values with increase in the size of mesh used.

Conclusions.

F a g e (5) published extensive data on the apparent rate of growth of the pilchard and sardine. His figures showed that the sardine of Brittany reached a greater average length in its first growing period than the Cornish pilchard, but that, in the later growing periods, the sardine was considerably smaller than the pilchard. L e D a n o i s (6) stressed this difference, suggesting that it implies a racial difference between the sardines of Brittany and the pilchards of Cornwall.

L e G a l l (7) published original data to show that the amount of growth of the sardine of Brittany and the pilchard of Cornwall is about the same at the end of the first growing period (l_1) but confirmed the earlier observers in the much smaller size attained by the sardine of Brittany in later years of its life as compared with the Cornish pilchard. He concluded that the growth of the sardine of the English Channel (including, of course, the Cornish pilchard) is quite different from that of the sardines of the Atlantic (including the sardines of Brittany).

More recently, however, B e l l o c (8) has shown that, in the Bay of Biscay to the south of Brittany, the average length reached at the end of the first period of growth (l_1) is as low as that found for the pilchard in the present experiments (8·5 cm.), and he is confirmed by

Desbrosses (9), who showed that, in the sardines of Brittany, the average value of l_1, though it may vary from year to year, had an average value (8·3 cm.), about equal to that found in the present experiments for the Cornish pilchard. Desbrosses was also well aware of the influence of the selective action of the drift-net on the composition of the catches; he gives data for the great variation in the apparent rate of growth from one sample to another, but, unfortunately, he gives no corresponding data as to the "moule" of the nets which provided the samples.

Finally, le Gall (10) in a recent review of the position, had to admit that, having regard to such circumstances as the long spawning-period of the pilchard and sardine, no "racial" significance could be attached to differences in the rate of growth, for fish spawned early in the season would have a long initial period of growth before the winter check, whereas fish spawned late in the season would have a short period of initial growth only.

To this difficulty two others can now be added. The apparent amount of growth can be influenced in a marked manner both by "Lee's phenomenon", and by the selective action of drift-nets having meshes of different sizes. The former will affect the apparent rate of growth according to the age-composition of the sample being examined; the latter will affect the apparent rate of growth directly.

In comparing the rate of growth of sardines from Brittany, for example, with pilchards from Cornwall, full regard must be had to the fact that the former consist largely of young fish, of one, two, or three years of age, whereas, among the latter, only mature fish of three years or upwards are found, 2-year-old fish being very rare. Further, the former are caught with drift-nets having a small mesh of more than 52 rows to the yard, whereas the latter are caught with comparatively large-meshed nets fishing at about 37—39 rows to the yard.

The small-meshed sardine nets must necessarily give catches consisting largely of small and young fish, which will, by "Lee's phenomenon", give high values for the apparent amount of growth in the first growing period (l_1) where this effect is not counter-balanced by the selection of the smaller fish. Among the older fish, these small-meshed nets must tend to select only the smaller specimens. On the other hand, the large-meshed pilchard nets will give catches consisting largely of older fish, which will, by "Lee's phenomenon", tend to give lower values for l_1 where this effect is not counter-balanced by the selection of the larger fish. And among the older fish, these large-meshed nets must tend to select the larger specimens.

In Figure 6 four curves are shown. These represent the apparent rates of growth of the sardines of Brittany, firstly according to le Gall (2), secondly, according to Desbrosses (9), and thirdly, of pilchards caught in the present experiments by the nets of mesh 36 and 46 rows to the yard, respectively, (Table II). Comparing the apparent rate of growth of the sardines of Brittany with that of the

pilchards caught by the net of mesh 36 rows to the yard, which is approximately the usual commercial net, it would seem that there is a decided difference, especially in the later periods of growth.

The average length reached by the end of the fourth and fifth growing periods (l_4 and l_5) is, in particular, much less in the sardines

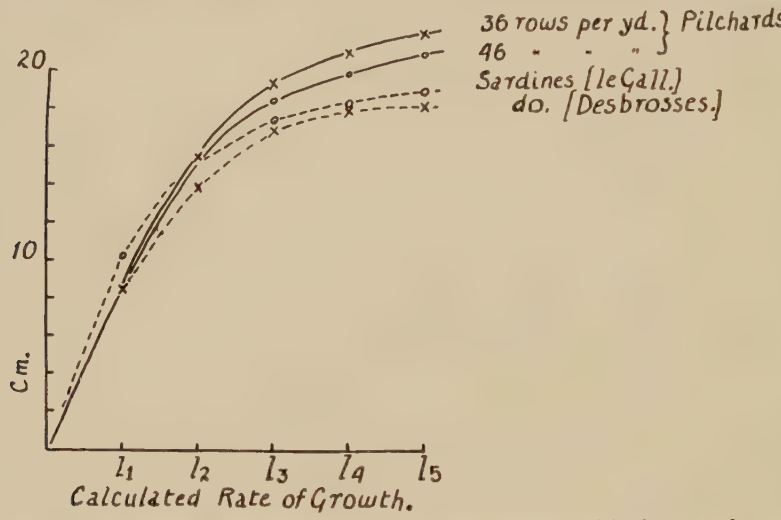


Figure 6. The apparent rate of growth of pilchards caught with the net of 36 rows to the yard, 46 rows to the yard, and of sardines. (le Gall and Desbrosses).

of Brittany than in the pilchards of Cornwall. But, in the present experiments, the smaller mesh (46 rows to the yard) gave a sample of pilchards with an apparent rate of growth slower than that of the fish caught by the mesh of 36 rows to the yard. It goes some way to bridge the gap between the apparent growth-rate of pilchards caught by the approximately "commercial" pilchard net of 36 rows to the yard, and le Gall's estimate of the apparent rate of growth of the sardines of Brittany, caught with a net of about 52—56 rows to the yard.

In Figure 7 the average values of l_2, l_3, l_4, and l_5, as estimated by le Gall (2), Desbrosses (9), and from the present experiments, are plotted against the "moule" of the nets used. The values of l_1 are omitted, because the French material includes a large proportion of 2-year-old fish, which are lacking in my material; further, the values of l_2 and l_3 from my results have been calculated from the 3- and 4-year-old fish respectively (Table II); both these precautions have been taken to avoid the complication introduced by "Lee's phenomenon", owing to the great differences between the age-composition of the samples of sardines of Brittany and the pilchards of Cornwall. The values for l_4 and l_5 have been taken from the French material on the assumption, arrived at by an inspection of the data, that most of the material there used for the estimation of these

later periods of growth had been caught by nets of "moule" about 70 in the case of Desbrosses's and 72 in the case of le Gall's data.

Figure 7 shows that the values of l_2 fall almost upon a straight line, with perhaps a very slight curve. These values, therefore, form a continuous series, increasing with the size of mesh used, from about 13 cm. in the case of a net of "moule" 59 to about 18 cm. in the case of a net of "moule" 100. The values of l_3, l_4, and l_5 are also from a continuous series, but fall upon curves. This is, of course, a reflection of the foreshortening of the rate of growth with increasing age, as

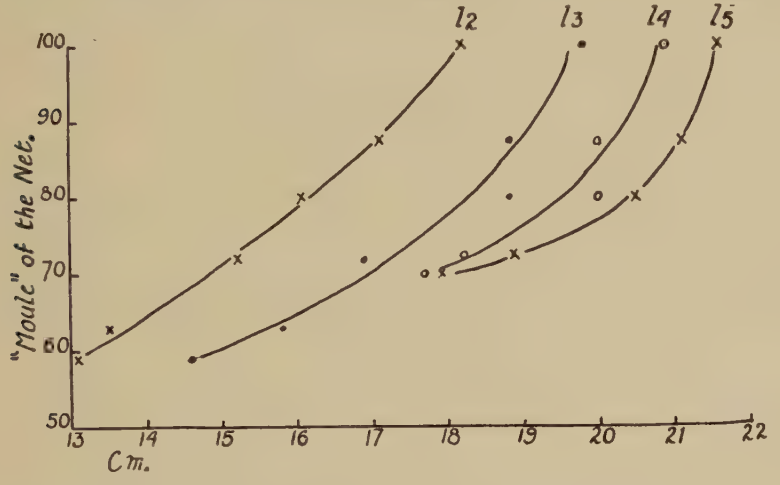


Figure 7. The relation between the size of mesh and apparent average length attained at the end of the second and fifth growth period.

Figure 6 shows. In the case of l_2, however, which is the length attained after a period of rapid growth, the spread of the lengths attained is wide enough to permit almost a linear relation between the size of mesh used and the apparent length attained.

Figure 7 shows that there is no discrepancy between the apparent rate of growth of the sardines of Brittany and the pilchards of Cornwall. The apparent difference in the rates of growth is consistent with the suggestion that it is based on samples selected, by the use of drift-nets of widely different size of mesh, from a population with approximately the same rate of growth.

Only a good series of hauls, with the same fleet of drift-nets, off the Cornish coast and off the coast of Brittany might make it possible finally to decide whether there is any residual difference in the rate of growth of the fish in these two regions. Until this point is settled there is no reason to believe, on grounds of the differences in growth-rate hitherto published, that the pilchards which appear off Cornwall and the sardines which appear off Brittany are not shoals of the same common stock, segregated by age and by sexual maturity, the stock aptly named the "Celtic" race by le Gall (10).

For the rest, the results of the experiments published in this paper make it very desirable to investigate the effect of net selection upon the apparent rate of growth of the sardine of Brittany also.

Summary.

Drift-nets having meshes of different sizes have a well-marked selective action on the pilchards caught. Nets having a mesh of 46, 42, and 36 rows to the yard, corresponding to a "moule" of 80, 87—88, and 100 respectively, caught fish, from the same shoals, of an average length of 20·7, 21·1, and 22·8 cm. and of an average weight of 73, 78, and 101 gm. respectively. The selective effect of these meshes on the age-distribution was very marked — the age-distribution of the sample caught by the small-meshed net of 46 rows to the yard was entirely different from that caught by the large-meshed net of 36 rows to the yard.

The selective action of the nets also affects the apparent rate of growth, the larger mesh selecting the larger fish of each age, and so giving, apparently, a higher rate of growth than those selected by the smaller mesh. This effect is found both in the average length of each year-class, and in the calculated rate of growth obtained by an examination of the position of the annual rings in the scale.

Finally, the selective action of the nets affects the apparent rate of growth, especially at the end of the first and second periods (the so-called l_1 and l_2) by the agency of "L e e's phenomenon". In the pilchard and sardine, these values decrease accordingly as they are calculated from the scales of older fish. A small-meshed net, selecting young pilchards, therefore tends to give a higher average value for l_1 and l_2 than a large-meshed net, selecting older pilchards; but this effect may be balanced by the selection of the larger specimens of each age-group by the large-meshed net.

It is shown that these experiments may explain to a large extent the differences in the apparent rate of growth between the pilchards of Cornwall and the sardines of Brittany.

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Untersuchungen über die inkretorischen Organe der Fische.

II. Die Metamorphose der Plattfische und die Bedeutung der Schilddrüse für diesen Vorgang.

Von

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Haifa, Palästina.

DIE Metamorphose vieler Tiere können wir aus ihrer stammesgeschichtlichen Entwicklung heraus verstehen. Die Ontogenie der Tiere, die eine Metamorphose durchmachen, lässt Rückschlüsse auf die Phylogenie zu. Die Amphibien, das klassische Objekt für Metamorphoseuntersuchungen, sind durch Umwelteinflüsse in ihrer Stammesentwicklung zur Aufgabe des ausschliesslichen Wasserlebens gezwungen worden und zum Landleben übergegangen. Wurde aber einerseits der Übergang vom Wasser- zum Landleben durch Umweltfaktoren erzwungen, so mussten andererseits die Anlagen zu dem durch den Aufenthaltswechsel bedingten anatomischen Umbau des gesamten Körpers als Innenweltfaktoren in den Tieren liegen. Als einen Teil dieser Innenweltfaktoren haben wir einmal die Gene anzusehen, die die Anpassung an das Landleben ermöglichen, und die von Harms als Landgene bezeichnet werden. Dazu kommen dann die Organe mit innerer Sekretion, die hauptsächlich den Wirbeltieren zukommen und die wir bei den Wirbeltieren als diejenigen Faktoren ansehen können, die die Realisation der Landgene bewirken. Dabei muss man annehmen, dass die äusseren Einflüsse im Organismus hauptsächlich durch Vermittlung des inkretorischen Systems wirksam werden. Hart hat darüber folgendes ausgeführt:— "Äussere Einflüsse auf den Organismus,

wie sie sich aus den Lebensbedingungen ergeben (Ernährung, Klima, Milieu), werden im wesentlichen nur durch Vermittlung des endokrinen Systems wirksam. Die äussere Einwirkung wandelt sich in eine innere um. Es findet eine Transformation der Kräfte statt, die den äusseren Einfluss verfeinert und spezialisiert. Die Umwandlung äusserer Kräfte in innere durch das endokrine System dient einer von diesem ausgehenden und beherrschenden Regulation des Organismus, infolge deren dem Individuum Anpassung an die Lebensbedingungen seiner Umwelt ermöglicht wird. Die Lebens- und Entwicklungsmöglichkeit der hier in Betracht kommenden Tiere liegt — in ontogenetischer wie in phylogenetischer Hinsicht — wesentlich begründet in diesem Gesetz der Umwandlung äusserer Kräfte in innere durch die endokrinen Organe."

Um zu den Amphibien zurückzukehren, so können wir sagen, dass in der Ontogenie dieser Formen der nicht mehr wirksame Umwelteinfluss auf die Gene, die die Landtierwerdung ermöglicht haben, ersetzt wird durch die Funktion der Schilddrüse. Die Funktion können wir als eine morphogenetische Wirkung der Schilddrüse ansehen, wie das in früheren Arbeiten Gley und Herbst ausgesprochen haben und wie es Hartmann in seiner allgemeinen Biologie bei der Besprechung der Harmozonorgane ebenfalls sagt. Die Metamorphose der Amphibien wird, wie wir das aus vielfachen Untersuchungen heute sicher wissen, ausgelöst und gefördert durch die Funktion der Schilddrüse und wir kennen aus früheren Untersuchungen (Sklower 1925) die histologischen Vorgänge an der Schilddrüse, die sich während der Metamorphose an ihr abspielen.

Einen Übergang vom Wasser- zum Landleben hat in den Jahren 1926/27 Harms bei seinem Aufenthalt auf Java bei Fischen beobachten und experimentell prüfen können. In den Familien der Periophthalmen und der Salariiden gibt es Formen, in der Mangrovevegetation lebend, die sich bereits weitgehend an einen Aufenthalt auf dem Lande angepasst haben. Sie vermögen es, viele Stunden lang in stark feuchter Luft auf dem Lande zu bleiben. Ganz nahe verwandte Formen haben aber dieses Stadium noch nicht erreicht. Die histologischen Untersuchungen dieser verschiedenen Formen ergaben, dass die Schilddrüse während des Übergangs von der rein im Wasser lebenden Form zur am Lande lebenden eine deutliche Funktionssteigerung aufweist, ein Vorgang, den man in Parallele setzen kann zur Funktion der Schilddrüse während der Metamorphose der Amphibien. Auf Grund dieser Befunde hat Harms dann die Formen, die noch nicht den Schritt zum Landleben gewagt hatten, mit Schilddrüsenstoffen beeinflusst und erreichen können, dass auch diese Formen zum Landleben übergingen, wenn auch noch nicht in dem ausgesprochenen Masse, wie es die stammesgeschichtlich schon weiter entwickelten Formen vermögen. Wir haben an diesem Befunde von Harms ein weiteres Beispiel für die morphogenetische und realisierende Wirkung der Schilddrüse auf die Landgene zu sehen. Aber nicht nur bei den Amphibien und den zum Landleben übergehenden Fischen finden wir eine derartige Wirkung der Schilddrüse. Auch bei den ständig im

Wasser lebenden Fischen gibt es Formen, die eine Metamorphose durchmachen und deren Verlauf abhängig ist von der Funktion der Schilddrüse.

In einer früheren Arbeit (1928) habe ich zeigen können, dass die Verwandlung des Aals aus der weidenblattförmigen Larve, die als *Leptocephalus* bezeichnet wird, zum Glasaal abhängig ist von der Tätigkeit der Schilddrüse als Harmozonorgan. Die histologischen Veränderungen, die ich an der Schilddrüse des Aals während der Metamorphose nachweisen konnte, waren genau dieselben, die früher bei der Metamorphose der Amphibien an der Schilddrüse gezeigt waren. Auch in der Lebensgeschichte des Aals wiederholt sich bei jedem Individuum der Vorgang, der in der Stammesgeschichte des Aals sich in langen Zeiträumen abgespielt hat. Die ursprünglich im freien Wasser des Ozeans lebende Form des *Leptocephalus* wurde durch die Strömung, besonders den Golfstrom, den Küsten Europas zugeführt. Hier an der Küste waren die Tiere gezwungen, von der rein planktonischen Nahrung zur Bodennahrung überzugehen und im Verein damit ihre Körperform zu ändern, besonders auch deshalb, weil sie in die Flüsse eindrangen und dort Hindernisse zu überwinden hatten, wobei ihnen die hohe Körperform hinderlich war. Sie wurden also zu dem drehrunden Aal, wie wir ihn heute aus fast allen mit dem Meere in Verbindung stehenden Binnengewässern Europas kennen. Nur noch in der frühesten Jugend hat sich die hochrückige Gestalt der ursprünglichen Form erhalten.

Eine andere Familie der Fische, die Plattfische *(Pleuronectidae)* zeigen in einem frühen Abschnitt ihres Lebensablaufs eine ausgesprochene Verwandlung. Die jungen Plattfische, z.B. Scholle oder Flunder, schlüpfen als kleine Larven aus und zeigen dabei eine durchaus "normale" Fischhaltung, d.h. sie schwimmen mit dem Rücken nach oben und der Bauchseite nach unten. Im Laufe der weiteren Entwicklung werden sie aber mit den Meeresströmungen den Küsten zugeführt. Damit sind sie aber gezwungen ähnlich wie die Aale, die Ernährung durch Plankton einzustellen und jetzt Bodennahrung aufzunehmen. Dabei ist ihnen die hohe Körpergestalt hinderlich und da es für sie schon an sich schwer sein muss, den schmalen hohen Körper im Gleichgewicht zu halten, kippen sie nach einer Seite über, sodass die eine Körperseite jetzt zur Unterseite des Fisches, die andere zur Oberseite wird. Dieses Umkippen wird nach Untersuchungen von K y l e wohl dadurch bedingt, dass eine Darmschlinge nach der Seite wächst, die dadurch ein Übergewicht bekommt und den Fisch zum Umkippen bringt. Bei den Formen, die noch eine Schwimmblase haben, wird das Umkippen dadurch gefördert, dass die Schwimmblase die zur Oberseite werdende Seite des Tieres gewissermassen hebt. Phylogenetisch haben wir uns die Plattfischwerdung wohl so vorzustellen, dass die nach K y l e den Blenniiden nahestehenden Vorläufer der Plattfische, die an einen hohen Salzgehalt gewöhnt waren, bei der Aussüssung des Meerwassers in der Nähe der Küsten das salzreichere Wasser aufsuchten, das in tieferen Schichten lagert, und dadurch allmählich zu Boden kamen, wo sie dann in der Stammesgeschichte ihre Metamorphose

durchmachten. Damit änderten sich natürlich auch die Nahrungsverhältnisse in einer Weise, wie sie für die Ontogenie der Tiere oben beschrieben wurde. Auch heute noch suchen die im Süss- oder Brackwasser lebenden Plattfischarten zur Laichzeit Meeresteile mit höherem Salzgehalt auf. Diese Laichwanderungen sind wohl darauf zurückzuführen, dass in der Phylogenie die Entwicklung an einen gewissen Salzgehalt geknüpft war und dass diese Notwendigkeit sich bis heute erhalten hat. Es ist sehr wahrscheinlich, dass die Eier der Plattfische sich in süssem oder brackigem Wasser nicht entwickeln.

Es lag nun nahe, auch bei der Metamorphose der Plattfische an eine ähnliche Wirkung der Schilddrüse zu denken, wie ich sie schon bei den Amphibien und dem Aal geschildert hatte. An einem Material von verschiedenen Entwicklungsstadien der Scholle *(Pleuronectes platessa)*, das bei Helgoland von der Biologischen Anstalt aus gesammelt war, habe ich die Schilddrüse bei den einzelnen Entwicklungsstadien untersuchen können. Im folgenden soll das Ergebnis dieser Untersuchungen mitgeteilt werden.

Das vorliegende Material wurde nach dem Entwicklungszustand der einzelnen Tiere in 10 Gruppen eingeteilt. Die erste Gruppe bestand aus vollkommen frei schwimmenden Larven, die noch keine Anzeichen einer Metamorphose boten. Die Gruppen 8—10 enthielten Bodenstadien, die ihre Metamorphose beendet hatten. Die Zwischengruppen waren Übergangsstadien.

Bei den jüngsten Formen fand ich eine Schilddrüse, die aus wenigen verstreut liegenden Follikeln bestand. Das Epithel der Follikel bestand aus kubischen Zellen mit einem grossen in der Mitte liegenden Kern. Mit Beginn der Verwandlung änderte sich das Bild. Die Follikel wurden zahlreicher und die Zellen des Follikelepithels ganz flach; der jetzt längliche Kern stellte sich mit seiner Längsseite parallel zur Follikelwand. Bei Tieren der Gruppen 4 und 5 war der Höhepunkt der Veränderung erreicht. Bei den weiteren Gruppen änderte sich das Bild wieder zu dem für die erste Gruppe charakteristischen. Die Follikel wurden wieder kleiner und die Zellen nahmen an Höhe zu, ebenso zeigten die Kerne eine Gestalt wie zu Beginn der Metamorphose. Dabei möchte ich nicht unerwähnt lassen, dass ich bei den letzten Stadien ein Kollabieren der Follikel feststellen konnte, wie ich es früher schon beim Aal beschrieben habe.

Die histologischen Befunde, die ich an der Schilddrüse der Plattfische während ihrer Metamorphose feststellen konnte, sind genau die gleichen, wie ich sie früher bei den Fröschen und dem Aal beobachtet habe. Aus diesen Befunden ist man, wie ich glaube, berechtigt, den Schluss zu ziehen, dass auch bei der Metamorphose der Plattfische — jedenfalls trifft es für das untersuchte Objekt, die Scholle, zu — die Schilddrüse eine morphogenetische Wirkung ausübt und dass sie die Gene der Plattfischwerdung realisiert.

Ich möchte noch hinzufügen, dass bei zwei Fischarten, der Bachforelle und der Karausche, die in ihrer Entwicklung keine ausgesprochene Metamorphose durchmachen, sondern sich kontinuierlich zu ihrer

typischen Form entwickeln, nach Befunden an einer Reihe von Schnittserien die Schilddrüse keine bemerkenswerten Funktionsschwankungen aufweist wie bei den bisher untersuchten Arten, Aal und Scholle. Auch dieser negative Befund scheint mir ein Hinweis auf die Beziehungen der Schilddrüsenfunktion zur Metamorphose der Wirbeltiere zu sein.

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Some Observations and Experiments on the Setting Behaviour of Larvae of *Ostrea edulis*.

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Introduction and Review of Previous Work.

IN recent years a number of papers has been published in America dealing with certain aspects of the setting behaviour of various species of oyster larvae. It is remarkable that although the European native oyster has probably been the subject of more scientific research than any other mollusc, yet up to the present the process of attachment of the larva has remained undescribed and very few experiments have been made which throw any light upon the setting behaviour of the larvae. In the United States on the other hand the actual process of attachment of the larva of *Ostrea virginica* was described by Nelson in 1924, and again in 1934 by Prytherch, the probable method of attachment having been deduced by Stafford in 1913 with a conspicuous degree of success from anatomical studies of the fully developed larvae and early spat.

In recent years also several careful studies have been made in America of the setting behaviour of the larvae of three species of oysters, viz., *O. virginica* (Prytherch, 1934); *O. lurida* (Hopkins, 1935 and 1937, and Bonnot, 1937); and *O. gigas* (Schaefer, 1937). Prytherch's paper is a thorough study of the process of setting in the American Atlantic oyster, in the course of which he arrives at certain rather revolutionary conclusions, notably concerning the prime influence exerted on the process of setting by small traces of copper salts in the surrounding medium. Prytherch's account does not agree very well with the earlier conclusions of Nelson (1924) concerning the details of the method of fixation,

and the behaviour of the larvae immediately beforehand, and some of these differences will be referred to later. Hopkins made a large number of experiments on the effect of the angle of the surface to the horizontal on the intensity of setting in *O. lurida,* and arrived at the conclusion that the undersides of horizontal surfaces present the most favourable site for attachment. His results show that as the angle of the surface to the horizontal increases so does the intensity of setting decrease. He used glass plates as his catching surfaces and infers that the selection of under surfaces is not due to a negative reaction to light. Schaefer confirmed Hopkins's conclusions on the influence of the angle of the surface, using, however, the larvae of *O. gigas* instead of *O. lurida.*

The setting process of larvae of the European oyster (*O. edulis*) has remained undescribed although the structure of the fully developed larva is well known, and the only recorded experiments made upon the setting behaviour are those of Thiéblemont (recorded by Herman (1937)), who compared the frequency of attachment on white and coloured limed tiles placed on the natural beds. The ordinary white limed tiles caught on the average slightly more spat than any of the coloured tiles. One of us (Cole, 1938) has described the fate of the larval organs of *O. edulis* after attachment, and this account includes a discussion of the function of the larval eyes. These eyes have been the subject of considerable controversy. Prytherch, working with the larvae of the American Atlantic oyster, came to the conclusion that they were not light-sensitive organs at all, but fulfilled a quite different function. There can, however, be no doubt whatever of the eye-like structure of these organs in the larva of *O. edulis,* as the works of Erdmann (1934) and Cole (1938) show. In America also Nelson (1925) described a response to light on the part of eyed larvae of *O. virginica,* which was not shown by younger larvae without eyespots. Prytherch on the other hand in the course of 8 years of experiment had observed no response to changes in light intensity or colour.

The observations and experiments described below were made at Conway, North Wales, during the years 1937 and 1938. The larvae studied were derived from breeding experiments carried out in a pair of large concrete tanks (see Cole, 1936), each of which contains about 85,000 gallons (382,000 litres) of water, so that the larvae were held under semi-natural conditions. Although the water in these tanks is not changed for several months and is not artificially circulated, yet there are good reasons for believing, after making due allowance for lack of tidal movements, that the setting behaviour of oyster larvae in the tanks follows closely that of larvae on the natural beds.

In 1938 the setting period in the Conway tanks extended from the third week in July practically to the end of August, and fully developed larvae were exceptionally abundant, giving very favourable conditions for experiments on their setting reactions. It was during this period that most of the work was done.

The Process of Attachment.

We had already in 1937 observed several oyster larvae in the act of setting, but unfortunately we were not able to get larvae to set on glass or other transparent material under the microscope, and hence were unable to observe distinctly the action of the foot in the closing stages of the setting process. In this respect we were no more fortunate in 1938, when, although we were able to observe any number of larvae setting on the insides of shells, we could not induce larvae to set on glass while observed under the microscope, although if left in a glass vessel without any other material for attachment, many of the larvae set on the glass. For this reason our account of the setting process necessarily lacks some of the detail present, for example, in the paper by Prytherch (1934) which actually includes cinematograph pictures of various stages in the process.

Setting is preceded, apparently in all cases, by an exploratory phase, during which the larvae crawl over the surface of the substratum with the velum withdrawn and the foot extended in front and dragging the shell. During this phase movement is brought about by the action of the cilia on the sole of the foot together with repeated contractions of the whole foot, the tip remaining stationary while the rest of the foot is strongly contracted and drags the body forward. Before they start crawling the larvae swim with the foot protruded between the valves anterior to the velum, the velum of course being uppermost. This period of swimming with the foot protruded constitutes the "searching" phase of Prytherch (1934).

Larvae may cease crawling and swim away to make contact again with other surfaces. It is fairly obvious that objects which present a maximum of horizontal underside are most likely, in still waters at least, to be reached by the greatest number of larvae, since for practical purposes the larvae may be said to swim vertically upwards only, lateral movements of any significance being produced only by the motion of the medium. This vertical swimming may in itself be sufficient to account for some of the results recorded later in this paper, which show a maximum intensity of setting on the underside of horizontal surfaces.

Crawling, alternating with periods of normal swimming, may extend over several days if no suitable surface for attachment is presented; this happens frequently if fully developed larvae are kept in clean smooth glass vessels without any other object to which they may attach. This ability to delay attachment, i.e., metamorphosis, is likely to be of considerable value in aiding survival of larvae carried to places where there are no suitable surfaces for attachment. The view that attachment may be delayed for a considerable time does not accord with the opinion of Erdmann (1934), who thinks that setting must be effected as soon as the byssus gland is ripe, and that if no suitable surface is presented at the "physiological moment", as it

were, then spontaneous discharge of the contents of the byssus gland may occur, after which attachment cannot be effected.

It is probable that the crawling phase occupies several minutes even under the best conditions when suitable surfaces abound. The larva crawls backwards and forwards rather irregularly over a few centimetres of surface, making smaller excursions in each direction, until to the observer the final site for attachment appears to have been selected. When the larva turns, the foot is retracted and thrust out in the new direction, generally more or less directly opposite to the previous line of movement, and the shell then slews around. During the early stages of the crawling period the foot may be extended to a length slightly greater than the diameter of the shell, but during the final phase it becomes much shorter and stouter. The excursions in each direction are then very short, usually not much greater than the width of the shell. When crawling ceases the behaviour of the larva is curiously reminiscent of that of a dog preparing its bed, but it is probable that what is actually happening is that the byssus material is being exuded by the larva over the spot where setting will finally occur. The larva rocks the shell backwards and forwards and to some extent from side to side while, we suppose, the byssus cement is squeezed out, then comes to rest, and the shell twists over on to its side, the left valve with the bigger umbo undermost, completing the setting process. Unfortunately the action of the foot during the last stages could not be made out, as it was generally hidden by the shell, but there was no evidence of any protrusion of the mantle as an aid in the distribution of byssus material such as Nelson (1924) describes. The byssus material hardens sufficiently in a minute or two to prevent the newly-set spat from being washed off by a jet of water from a pipette. Larvae dislodged immediately after setting were not observed to attempt to set a second time. For a few hours after attachment the velum is frequently protruded with the cilia beating strongly, but appearing slightly abnormal. As described by Cole (1938) the dissolution of the velum is far advanced within 24 hours after attachment, while within 48 hours it has completely disappeared.

The behaviour of larvae of *O. edulis* when about to set, as described above, resembles so closely Prytherch's (1934) description of the movements of larvae of *O. virginica* that we have thought it worth while to reproduce some of this author's description.

On page 62 Prytherch writes, "At the beginning of the crawling phase the larva moves for a considerable distance in almost a straight line, until on reaching the edge of the object or some obstruction, it turns about and proceeds in the opposite direction. Later the larva reverses its direction in crawling more frequently and as the time of setting approaches, moves but a few millimeters back and forth in one spot. In order to reverse its direction in crawling, the larva draws the foot into the shell and protrudes it from the posterior end after which the shell and body are spun around to the left and crawling resumed as before.

During the crawling phase the foot gradually changes from a long and slender shape to one that is short and broad .... The end of the crawling period can easily be recognised by the slow, forced movements of the larva, the shape of the foot, and the frequent backward and forward crawling of the larva over an area scarcely a millimeter in diameter."

The above description might apply equally well to the larvae of *O. edulis*. With regard to Prytherch's observations of the laying of a fine byssus trail by the larva during the crawling period, we have little direct evidence either way, but we regard it as possible that such a trail is laid by European oyster larvae during the final phases of crawling.

The belief, so frequently expressed in accounts of the life history of the oyster published in the last century, that fixation occurred when the shell became so heavy that the larvae were unable to swim and sank to the bottom, is totally erroneous, as the swimming powers of the larvae are undoubtedly greatest during the period immediately preceding attachment.

The Influence of the Angle of the Surface on Attachment.

Hopkins (1937) and Schaefer (1937) have shown, with larvae of *O. lurida* and *O. gigas* respectively, that under natural conditions the greatest intensity of setting occurs on the underside of horizontal surfaces, while the intensity of setting falls off progressively as the angle of the surface to the horizontal increases. In both the above-mentioned accounts the *upper* surface of a plate inclined at an angle of 45° is considered as being at an angle of 135° to the horizontal and other surfaces accordingly. For the sake of uniformity we also have adopted this notation.

In order to test the reactions of European oyster larvae to surfaces at different angles to the horizontal a wooden frame was made which would hold three slates of equal size, one horizontal, another vertical and the third at an angle of 45°. The slates were of the type used by children for slate pencil work and had of course a smooth finish on both sides. Each side had an area of approximately 400 sq. cm. The three used were selected from the same batch and appeared to be uniform in finish, but to overcome any differences which might exist between them they were frequently interchanged during the course of the experiment. After both frame and slates had been thoroughly soaked they were hung in position at about half depth (3 ft. below surface) in a corner of one of the large breeding tanks at Conway. The frame was removed daily at intervals of approximately 24 hours and the spat counted on both surfaces of the three slates. The spat were removed after being counted, and the slates washed and returned to the tank. This was repeated daily over a period of four weeks, the slates being transferred to another tank when setting had ceased in that first used. During this period very large numbers of larvae

Table 1.

Quantity of oyster larvae attaching daily to each surface (area approx. 400 sq. cm.) of three slates, one held horizontally, another vertically, and the third at an angle of 45°.

Date	Tank	0°	45°	90°	135°	180°
29/7	B	25	16	0	0	0
30/7	,,	15	8	0	0	3
31/7	,,	246	118	2	2	19
1/8	,,	659	210	9	16	10
2/8	,,	762	449	19	58	32
3/8	,,	485	420	23	40	29
4/8	,,	306	166	7	7	6
5/8	,,	932	347	7	33	32
6/8	,,	545	303	11	27	23
7/8	,,	1369	434	10	34	31
8/8	,,	431	86	4	10	11
9/8	,,	70	16	0	1	1
10/8	,,	2	1	0	0	0
11/8	A	1030	225	2	5	10
12/8	,,	2288	1617	10	29	12
13/8	,,	579	218	2	4	2
14/8	,,	526	368	3	18	0
15/8	,,	800	753	9	18	4
16/8	,,	586	197	0	12	5
17/8	,,	263	85	0	0	0
18/8	,,	170	39	0	1	0
19/8	,,	54	2	0	0	0
20/8	,,	117	24	0	0	1
21/8	,,	22	5	0	1	0
22/8	,,	26	3	0	0	0
23/8	,,	69	10	1	0	1
24/8	,,	21	0	0	0	0
25/8	,,	9	3	0	0	0
Totals		12407	6123	119	316	232

were attaching themselves. The results are presented in Table 1. In this table 0° represents the underside and 180° the upperside of the horizontal slate, while 135° represents the upperside of the slate at 45° and 45° the underside. The vertical slate is represented as 90°, and the total of spat caught on the two sides of this slate has been halved to give the figure in column 5.

The results are quite clear-cut and consistent. The underside of the horizontal slate offers a surface for attachment about twice as favourable as the underside of the slate at 45°, while the vertical slate and the upper surfaces of the horizontal and 45° slates were less than 5 % as favourable. It will be seen that the vertical surfaces caught least spat of all, only about one-half the quantity attaching to the upper surface of the horizontal slate and about one-third the quantity caught by the upper side of the inclined slate. The upper surface of the latter appears to be slightly more favourable therefore than that of the horizontal

slate. Although in the waters of our tanks there is of course no silt, yet in practice the upper surfaces of both the inclined and the horizontal slates caught a certain amount of grit and algal material each day. This must have reduced the effective area for setting but could not be said to have fouled the plates, and we do not believe that it had any significant effect on the results. Further evidence for this view is provided by the results of the experiment described below.

In order to eliminate as far as possible the effect of grit, etc. on upper surfaces, which may have interfered with the last experiment, another test was arranged in which 36 oyster shells were placed inside a covered tray about 9 inches below the surface of the tank and a daily count made of the spat caught on the concave surfaces. Eighteen shells were placed with the concave side downwards and an equal number with the concave side upwards, and the two groups were interchanged daily. All were protected from falling particles by the cover of the tray which extended some distance beyond the shells all around, and the possible differential effect of shading was also very much reduced as all the shells were shaded, although those surfaces facing upwards would presumably still receive more light than those facing downwards. The cover was raised about 6 inches above the shells and all the sides of the tray were open, while the slatted floor allowed access to the shells from below. The results are shown in Table 2. About twelve times as many spat set on the shells with the concave side downwards, which appears to prove that even when both upper and lower surfaces are equally clean the lower surface is very much more favourable for attachment.

Table 2.

Quantity of spat setting daily on the inner concave surfaces of 36 oyster shells. Eighteen shells were placed with the concave side upwards and eighteen with the concave side downwards.

Date	19/8	20/8	21/8	22/8	23/8	24/8	25/8	26/8	Totals
Shells with concave surface									
up	0	1	7	1	10	5	13	10	47
down	7	13	44	71	130	68	144	83	560

In the first series of experiments it was very noticeable that on the underside of the slate inclined at an angle of 45° the larvae tended to set most frequently near the upper free edge of the slate, indicating, we believe, a tendency on the part of the fully developed larva to crawl upwards against gravity on an inclined surface. This tendency of the larvae to set on the higher parts of the inclined slate was always present and had been noticed also on slates resting on the tank bottom and leaning against the side, generally at about 60° to the horizontal. On such slates, which remained in the tanks for several months and caught several thousand spat, there was a gradation in the intensity of setting from the tank bottom upwards. The higher parts of these slates which caught the most spat would also be those

where the intensity of light was least, but this was not so on the inclined slate in the special frame, for the upper free edge would, if there was any difference at all, receive rather more light than the rest of the slate.

This clearly marked tendency of the larvae to move upwards against gravity on an inclined surface is apparently also a characteristic, although to a lesser degree, of the larva of *O. virginica.* Prytherch (1934) placed 10,000 fully developed larvae of this species in a tall cylindrical vessel and noted the distribution of the attached spat after 24 hours. The majority attached themselves to the bottom of the cylinder and the first 4 inches from the bottom of the glass walls, but some moved upwards as far as 8 or 9 inches. Prytherch states that the result of this experiment "shows clearly the tendency of the larvae to crawl upward on inclined or vertical surfaces", a conclusion with which few people would be inclined to agree. That it shows some slight tendency to crawl upward one must admit, since in all probability the majority of the larvae began their crawling on the bottom of the cylinder; were it possible, however, to repeat this experiment with larvae of *O. edulis,* the majority would almost certainly be found to set near the water-level instead of near the bottom, for on the inclined slates a great many larvae actually set within a millimetre or two of the upper edge. It is, however, difficult to induce larvae of *O. edulis* to set on smooth glass and therefore an experiment similar to that of Prytherch's was not made, but it has been observed that of the small number of larvae setting in the laboratory on the glass of bowls or beakers the majority attached themselves very near the water-level.

The orientation of the individual larvae when setting on an inclined or vertical surface is of some interest, as Prytherch (1934) states that "when oyster larvae set upon a vertical surface, they invariably place the shell with the dorsal edge or hinge uppermost". This is very nearly true also of larvae of *O. edulis,* although a small proportion also set in other positions, e.g., of 50 newly-set spat, whose orientation on the slate inclined at 45° was noted, 38 had set with the hinge up, while 12 had the hinge down; and again of 20 set at another time on the same slate, 18 had set with the hinge up, one with the hinge to the side and only one with the hinge down.

The Influence of Light upon Attachment.

As already noted earlier, no doubt now exists as to the presence of true eyes in the larva of *O. edulis.* It would not therefore be surprising to find that the fully developed larva reacted to changes in light intensity and that this reaction to light played some part in the selection of a site for attachment. Up to the present only Nelson (1925) has succeeded in demonstrating any reaction to changes in light intensity on the part of oyster larvae. He says of the larvae of *O. virginica* that "in the presence of light these 'eyed' larvae of the oyster are stimulated and continue moving until they get into a shaded

place, where they become quiescent". He further states that younger larvae without eyespots do not behave in this way. Prytherch (1934), however, denies that larvae of this species exhibit any reactions to changes in light intensity or colour and, moreover, is of the opinion that the so-called eyes are not eyes at all, but serve a quite different function.

Hopkins (1937) has studied the influence of light on the setting behaviour of larvae of *O. lurida* under natural conditions in Puget Sound, Washington, and has found that similar numbers of larvae set on the under surfaces of clear and darkened glass plates, indicating no selection of shady places by the larvae when ready to set. He demonstrates also that in this species setting proceeds equally well at night as during the day and therefore concludes that light is not an orienting factor in the setting behaviour of this species.

Table 3.

Quantity of oyster spat setting daily on the under surfaces of 2 pairs of glass plates, one pair clear and the other pair coated on the upper surfaces with black paint.

Date	Tank	Clear	Black
31/7	B	2	4
1/8	,,	8	20
2/8	,,	16	40
3/8	,,	13	42
4/8	,,	8	24
5/8	,,	23	50
6/8	,,	37	99
7/8	,,	29	116
8/8	,,	7	32
13/8	A	0	1
14/8	,,	0	4
15/8	,,	15	86
16/8	,,	2	8
17/8	,,	7	36
18/8	,,	14	21
19/8	,,	14	48
20/8	,,	29	94
21/8	,,	4	10
Totals		228	735

In order to explore the question of the relation of light to setting in larvae of *O. edulis* counts were made daily of the larvae attaching themselves to the under surfaces of two pairs of glass plates, one pair being clear and the other coated on the upper surface with black paint. The four plates were cut originally from the same sheet of glass, one surface of which was finely ground; this surface was presented to the larvae for attachment as they do not fix readily to smooth glass. The four plates were hung horizontally in a corner of one of the tanks at Conway at a depth of about 3 feet. The results of this test are shown in Table 3. This table shows a well-marked preference

on the part of the larvae for the underside of the dark plates, the total quantity of larvae attaching themselves to the clear plates being less than one-third of that found on the dark plates. The results are consistent in both tanks throughout the 18 days that the experiment was carried on.

If such a selection of shady places for attachment exists it should not be manifest during the night, when for practical purposes the intensity of darkness beneath both black and clear plates would be the same. In an attempt to substantiate this hypothesis counts were made of the larvae attaching themselves to the plates during seven-hour periods of darkness, comparing these with other seven-hour periods of daylight during the days preceding and following. The results of this test are shown in Table 4, the period of darkness being included under the date on which it began; for example, the night of

Table 4.

Quantity of oyster spat attaching to the under surfaces of pairs of clear and black-coated glass plates during 7-hour periods of daylight and darkness.

Date	Daylight 6·30 a.m.—1·30 p.m.		Daylight 2·30 p.m.—9·30 p.m.		Darkness 10·30 pm—5·30 a.m.	
	Clear	Black	Clear	Black	Clear	Black
$^{18}/_{8}$	—	—	3	39	11	8
$^{19}/_{8}$	0	1	16	63	9	13
$^{20}/_{8}$	5	18	3	10	1	0
Total 2 plates	5	19	22	112	21	21

August 18th—19th is tabulated opposite August 18th. The test was a short one, for the black plates were repainted on the 21st and the fresh paint near the setting surface proved distasteful to larvae for the remaining few days of the experiments, yet the results appear clear-cut and are extremely interesting. In five daylight periods the two dark plates caught practically five times as many spat as the two similar clear plates, while in three periods of darkness the black and clear plates caught the same quantity of spat. The conclusion to be drawn is undoubtedly that during daylight the larvae tend to select a shady situation for attachment.

There remained to be compared the actual intensities of setting during daylight and darkness. To elucidate this question counts were made of the total number of larvae attaching themselves to the inner concave side of 25 oyster shells during seven-hour periods of daylight and darkness. The shells were placed concave side downwards on slatted wooden trays, five shells being held about nine inches below the tank surface, ten at mid-depth (i.e. 3 ft.) and ten more about nine inches from the bottom (i.e., about 5 ft. 3 in. from the surface). The results of these counts are given in Table 5. The periods of darkness are entered opposite the day on which they began; for example, the night of August 17th—18th is shown against August 17th.

Table 5.

Quantity of oyster spat attaching to the inner concave surfaces of 25 oyster shells during 7-hour periods of daylight and darkness. Five shells were held near the surface, ten at mid-depth, and ten near the bottom of the tank.

Date	Daylight 6·30 a.m.—1·30 p.m.	Daylight 2·30 p.m.—9·30 p.m.	Darkness 10·30 p.m.—5·30a.m.
17/8	—	136	28
18/8	60	201	55
19/8	139	115	24
20/8	38	74	32
21/8	71	90	12
22/8	65	12	49
23/8	185	—	—
Total 7 periods	558	628	200

The results in Table 5 are consistent with one slight exception on August 22nd when only 12 spat were noted after the p. m. daylight period, while 49 set during the following dark period; however, the number setting during the succeeding daylight period was very much greater than either. This table shows a marked tendency for the larvae to attach themselves during the hours of daylight, for the average number of larvae setting per daylight period was about three times that setting during a period of darkness of the same length. The results of Hopkins (1937) indicate that in the field this tendency is overlain by more important tidal influences. Further discrepancies between his observations and our own will be referred to later in the discussion.

The Influence of Depth upon the Intensity of Attachment.

By suspending several series of baskets of shells at different depths below the surface in Puget Sound, Washington, Hopkins (1937) was able to show that larvae of *O. lurida* set most abundantly within the first 20 or 30 inches from the surface of the water. The shells placed only a few inches below the surface caught very few spat, but those placed at 14—19 inches from the surface caught on the average about twice as many spat as others at a depth of 99—104 inches.

In the tanks at Conway it had been found previously that a tower of the curved limed tile collectors built up from the tank bottom (depth 6 ft.) to the surface showed no constant variation in the intensity of setting from bottom to surface. The spat were distributed more or less evenly from bottom to surface, and this observation, frequently repeated, led to a belief that larvae set equally readily at all depths in our tanks. For this reason no change was made in our practice of disposing the tile collectors in bundles on the tank bottom, and whenever fully developed larvae were abundant these tiles on the bottom invariably caught a good crop of spat.

A more searching test was, however, made during 1938, and trays of shells were hung at three different levels in the tank and a comparison made of the quantity of spat caught at each level. Ten shells were placed concave side down on a slatted wooden tray about nine inches from the tank bottom (depth of tank — 6 ft.), ten on a similar tray at half depth (3 ft.), and five on another tray nine inches below the surface; all the groups of shells were similarly spread out. Counts were made of the spat which attached themselves to these shells and, to increase the uniformity of the conditions, the actual shells used were interchanged occasionally. Counts were made three times every twenty-four hours, after seven-hour periods of daylight (two) and darkness (one), and in this way information as to the variation in the depth distribution of spat during day and night was also obtained. The results are shown in Table 6. In this table a

Table 6.

Quantity of oyster spat attaching to the inner surfaces of groups of oyster shells held 9 in. below the surface, at mid-depth (3 ft.) and 9 in. above the bottom (depth 5 ft. 3 in.) in the Conway tanks, per 7-hour period of daylight or darkness. 10 shells were used at mid-depth and near the bottom but only 5 near the surface, so that the totals recorded under "Surface" are double the actual counts made.

Date	Daylight 6·30 a.m.—1·30 p.m.			Daylight 2·30 p.m.—9·30 p.m.			Darkness 10·30 p.m.—5·30 a.m.		
	Surface	Mid-depth	Bottom	Surface	Mid-depth	Bottom	Surface	Mid-depth	Bottom
17/8	—	—	—	240	16	0	42	4	10
18/8	92	11	3	344	28	1	78	10	22
19/8	226	19	7	174	25	3	34	6	1
20/8	44	15	1	124	11	1	52	6	0
21/8	112	11	4	168	6	0	20	2	0
22/8	82	23	1	20	1	1	80	7	2
23/8	330	12	8	—	—	—	—	—	—
Total 7 periods	886	91	24	1070	87	6	306	35	35

period of darkness is shown opposite the day on which it began. As the records near the surface were taken on five shells only, in the tables the actual counts on these five shells have been doubled to make the totals comparable with those on the bottom and mid-depth shells. Five shells only were employed at the surface as a trial had shown that each shell caught a considerable number of spat in this position, and since most of the counting had to be done either very late at night or very early in the morning the number of shells was reduced.

Table 6 shows striking differences in the intensity of setting on the three groups of shells. The shells near the surface caught on the average about ten times as many spat as those at half-depth (i.e., 3 ft. below the surface). The shells near the bottom caught least of all during the day and considering the millions of settling larvae in the

tank they caught a very meagre crop indeed. During the night there was no apparent difference between half-depth and bottom samples, but the marked preference for the surface water was still evident. The improvement in the intensity of setting near the bottom during the hours of darkness seems to imply a variation in the behaviour of the larvae as between day and night and this change is referred to again in the discussion.

The Attachment of Spat under Natural Conditions.

Oyster larvae have been known, in certain circumstances, to attach themselves to an extremely wide variety of surfaces, varying from the inside of empty oyster shells on the one hand, as perhaps the most popular, to seaweed on the other, as perhaps the least favourable. Nevertheless there are always very marked differences in the intensity of setting on the various surfaces and it is obvious that some are very much more favourable than others for attachment. Certain surfaces have been known for a very long time to be exceptionally favourable for attachment, e. g., oyster shells and tiles coated with a lime, or lime and sand, mixture. Other surfaces have been recognized as being intrinsically unsuitable, e.g., very smooth surfaces such as glass, seaweed, etc., and are only occasionally favoured, usually when other better surfaces are not available. Whatever the surface, if larvae are to fix to it, it must first of all be clean and free from silt or slimy algal growths, and for this reason it is recognized on all hands that materials employed as collectors of oyster spat should be placed in position in the sea not more than a week or two before the spat is ready to settle.

On the natural oyster beds clean surfaces suitable for attachment are not numerous and are often widely scattered, comprising principally the insides of the shells of recently dead oysters and other molluscs, the new shell growth of living molluscs, particularly oysters, and the clean edges of shells containing living molluscs. In addition summer dredging over the grounds, for the purpose of removing enemies and collecting brood for replanting, uncovers a certain amount of clean surface among shells and stones on the bottom. It has always been recognized by practical oystermen that it is necessary to supplement the natural supply of clean surfaces for attachment by laying down during the summer bleached oyster or cockle shell or other cultch, but it is doubtful whether the extreme paucity on most beds of natural surfaces in a suitable condition for attachment of larvae is properly appreciated. Investigation of the abundance and growth of oyster larvae in the Helford River, Cornwall, during 1938, an unusually cold summer, proved conclusively that sufficient larvae reached settling size to give a very heavy natural spatfall, and suggested that the scarcity of suitable material for attachment was the principal factor limiting the spatfall. A large area of the bottom in the Helford River is covered with old shell cultch, but it is clear that very little of

this old shell is in a suitable condition for attachment, despite repeated disturbance by dredging during the summer months.

Table 7.

Attachment of oyster spat on undisturbed oyster bed.

Material to which attached	Mussel shells	Shells of still living mussels	Oyster shells	Queen shells	Other mollusc shells	Stones	Indeterminate
Number	12	17	6	1	3	2	6

Table 7 shows the results of the examination of forty-seven large oysters collected from an area untouched by normal dredging activities around low-water mark of spring tides on the Helford River, Cornwall. The area concerned was situated on the shoreward side of the regular dredge beds and consisted of the inner edge of the flats, the soil being a stiff sandy mud carrying a fair amount of old shell and numerous clumps of mussels. Large oysters, at least 3 years old, were collected systematically, irrespective of their attachment. It will be seen that under such undisturbed conditions suitable surfaces for attachment and survival were provided principally by the shells of dead molluscs, apparently recently dead in most cases when attachment occurred, and the free edge of shells containing living molluscs. The marked preference shown for the clean edges of shells containing living mussels, in an area where there was plenty of old shell, tends to confirm the belief that such old shell cultch is rarely in a suitable condition for attachment. It was noticeable that despite the abundance during the summer in this particular estuary of the freshly emptied shells of "queens" (*Chlamys (Aequipecten) opercularis*), only one oyster in this sample was found attached to this kind of shell. This comparative neglect of the clean surfaces provided by freshly dead "queen" shells was general on all the oyster beds in the Helford River.

It is probable that on many natural beds the lack of clean surfaces for the attachment of larvae is one of the main causes of the poor spatfalls experienced during recent years. Even where extensive cultching of the bottom with oyster or cockle shell is practised the shell is frequently laid down at a fixed time irrespective of whether the season is early or late; nor is there any precise knowledge of the movements of the larvae, with the result that on many occasions no spat is caught. The whole matter of the liberation, dispersal, and settling of oyster larvae under natural conditions requires very careful study if the laying of collectors is to be done successfully.

Discussion.

The large tanks in which the tests described above were made are used annually for oyster breeding experiments. The spat collectors (limed tiles) are placed on the tank bottom, the top tiles of a bundle being about ten inches above the tank bottom. The amount of surface suitable for the attachment of larvae in the upper parts of the tanks, that is to say, above the bottom ten inches where the tiles are situated,

is very small, comprising chiefly a band about six inches wide around the walls of the tank at the surface, where the constant lapping of the water keeps the wall free from mucilaginous algal growth. This is the only part of the tank walls free of such algal growth in a normal season and it is noticeable that it usually catches a great many spat (see Cole, 1936). The rest of the larvae must attach themselves to the tiles at the bottom if they are to fix at all, and in practice the tiles are always well covered when settling larvae are abundant. It has been shown, however, that the larvae attach themselves most readily to objects near the surface of the water, and it would appear that if sufficient clean surfaces were provided just below the water-level the tiles on the bottom would catch very few spat. When clean surfaces near the water-level are not available the larvae clearly have the power to delay attachment and metamorphosis until they reach the collectors at the bottom of the tank. Whether there is any active searching for clean surfaces is not really known, for although the behaviour of the eyed larvae prior to setting suggests active seeking and selection, their swimming habit does not appear to differ from that of the earlier stages. The ability to delay metamorphosis until a suitable surface is presented is similar to that possessed by the larvae of several species of polychaete worms (Wilson, 1938), and must be of paramount importance in aiding survival under natural conditions, since on many oyster beds suitable objects for attachment are few and far between.

The results presented earlier in this paper suggest that in any breeding experiment the potential spatfall might be increased by raising the collectors to a position near the surface, so as to eliminate loss of larvae during the period elapsing between the attainment of full development and actual fixation to the tiles on the bottom. Such a manoeuvre may not prove to be feasible, especially with heavy collectors such as the limed tiles used at Conway. The building up of towers of collectors from the tank bottom to the surface does not have the required effect, as we have seen, and we may now consider the reason for the more of less even distribution of spat on such a tower. Oyster larvae, broadly speaking, swim vertically upwards only; this is true of all species of oysters (see, for example, Roughley, 1933, Hori, 1933, and Hopkins, 1937). Lateral movements of any importance are produced only by the motion of the medium. In the comparatively still waters of the tanks at Conway such lateral movement of the water during ordinary weather is probably not very marked; consequently to reach a surface larvae must usually approach it from almost directly underneath. In a vertical tower of tiles it is almost impossible for any considerable quantity of larvae to reach the tiles by this method as the tower is complete from bottom to surface, and most of those which set on the tiles in the tower must have drifted laterally on to them with the motion of the water. In this way a more or less even distribution from bottom to surface would be produced such as has in fact been observed.

The vertical swimming habit of oyster larvae is not sufficient in itself to account for the high intensity of setting observed on the under surface of shells held near the surface (see Table 6) and the low intensity of setting on similar shells lower down. Although it is clear that the greater the depth of the column of water below the shells, the higher will be the number of larvae reaching the shells, and attaching, yet the difference between the intensities of setting at the surface and at mid-depth are too great to be explained in this way, unless one postulates great differences between the densities of larvae in the upper and lower halves of the tank. Investigation of the vertical distribution of larvae during the day-time by means of a simple type of sample bottle let down to various depths, indicated that although the distribution of larvae was not quite uniform even in calm weather, the abundance of larvae in the upper half of the tank was less than twice that in the lower half. When these investigations were made eyed larvae were abundant in the tank, but their distribution appeared to be similar to that of earlier larvae. The distribution noted, when considered in relation to the vertical swimming habit of the larvae, is quite inadequate to explain the very large differences between the intensities of setting at surface and mid-depth as shown in Table 6, and we are unable to offer any satisfactory explanation of them.

It is clear from the high intensity of setting near the surface that the preference on the part of larvae for a shady place for attachment is not strong enough to reverse the normal swimming habit, which tends to carry the larvae away from the darker and deeper parts and towards the surface of the tank. Larvae reach the bottom of the tank by closing their shells and dropping and it is probable that they do not normally do this until stimulated by the presence of some unfavourable element in the water in their immediate neighbourhood. That larvae must normally swim indefinitely is evident by the success of oyster culture in the Norwegian polls (see G a a r d e r and B j e r k a n 1934) where the larvae pass their whole free-swimming period in a stratum of saline oxygenated water only a metre or so in depth, and far removed from the bottom where conditions are very unfavourable. It appears as if active selection of a shaded situation only occurs when the larva begins to crawl, resulting in a greater intensity of setting on the underside of objects. This habit of seeking a darkened place for attachment has probably a definite survival value, as such situations are also free from silt and algal growths. On the other hand they are apparently equally favoured by the larvae of many ascidians and worms.

The results recorded in Tables 3 and 4 seem to prove beyond doubt the existence of a real preference for shady situations for attachment, despite the failure of H o p k i n s (1937) to demonstrate any such response in the larvae of *O. lurida.* These two sets of results may not be as contradictory as they seem for it must be remembered that in the dikes on the oyster grounds at Olympia, Washington, where

Hopkins worked, the plates were covered at high tide by twelve to fifteen feet of water, and it may be that the optimum condition for setting is a reduced light intensity, such as would be provided below a series of clear plates in that depth of water, rather than absolute darkness. In the Conway tanks the plates were covered with but three feet of water, and that very clear and completely free from silt, so that the intensity of light beneath the plain glass plates would be comparatively high, while below the black-coated plates it would not be completely dark. It is unlikely, we think, that larvae of such closely related species should differ fundamentally in behaviour, and in this opinion we are supported by Orton (1937).

The general falling off in the intensity of setting, and the improvement in that on the shells at the bottom, during the night, are both somewhat difficult to explain. The improvement in setting near the bottom of the tank might be interpreted as due to a decrease in the swimming activities of the larvae at night resulting in a general sinking towards the bottom, and the general reduction in the intensity of setting during the hours of darkness may be a result of this same tendency.

It is obvious that the vertical swimming habit of the larvae will, in the comparatively still waters of tanks, bring the maximum quantity of larvae into contact with the under surface of horizontal objects and the minimum into contact with vertical surfaces, while the majority of the larvae reaching the upper surfaces of a horizontal or inclined slate will get there merely by falling upon it from above, hinge downwards moreover, and so in a posture unsuitable for crawling. These facts, together with the demonstrated preference for a shady site for attachment, are not, we think, sufficient in themselves to account for the results recorded in Tables 1 and 2. We are inclined to suppose that the crawling larva must exercise a more or less discriminating selection of angle of surface. If no such selection exists it is very difficult to explain why the intensity of setting on the under surface of the plate at 45° was only half that on the under surface of a similar horizontal plate; the expected figure would be about ¾ (sin 45°) on the basis of the number of larvae reaching each surface in the course of their normal vertical swimming.

Hopkins (1937) and Schaefer (1937) accounting for somewhat similar results recorded on clear glass plates at different angles, both put forward a purely mechanical explanation based on the vertical swimming habit and the swimming position of the larva with the foot and velum upwards, but in as much as Hopkins obtained ten times as many spat on horizontal plates as on the same area inclined at 45°, and Schaefer four times as many, we do not consider that such an explanation covers all the facts. We are inclined to suppose that the crawling larva must discriminate between surfaces at different angles, and would point out that the differences between horizontal and inclined surfaces can probably be appreciated by the larva only while crawling. According to our observations and those of

Prytherch, the larvae of *O. edulis* and *O. virginica* always go through a crawling phase, which occupies at least several minutes and is a necessary preliminary to setting. It appears to be during this crawling phase, too, that the larvae of *O. edulis* test the surface for that slight roughness and shade which they prefer.

The results described herein may prove to be of some practical importance. The discovery that larvae set most readily near the water surface in tanks indicates that the potential spatfall from tank breeding experiments might be increased by providing collectors near the surface. The limed tiles at present used are clearly not suitable but there appears to be a good case for suspending trays of shell cultch or other light collectors near the surface, while retaining the tile as the main type of collector. In the most recent tank experiments at Conway (see Cole, 1939) the quantity of larvae reared to settling size has been very high, many millions in all, and the tile collectors have in general been too thickly coated with spat. In such a year the removal of a million or two larvae, by placing twenty or thirty trays of shell cultch in the tanks for a day or two, would not interfere materially with the spatfall on the tiles, while the shell cultch if spread on a patch of cleared ground on an oyster bed might produce a valuable crop of brood.

On the natural beds, where there is every reason for supposing that larvae will behave in the same way, recognition of the fact that spat set most readily near the surface opens up the possibility of utilizing floating trays of cultch for the collection of spat. Such floating trays of cultch have already been used with success in Canada (Needler, 1933) and on the Pacific coast of America (Hopkins, 1937). One of the chief problems of the British native oyster industry today is the expense of producing native brood under the present system, for on account of meagre and widely scattered spatfalls, the cost of dredging up, culling and replanting brood oysters is inordinately high, and compares unfavourably with the cost of imported French brood. During most seasons larvae are abundant on British oyster beds (see Orton p. 137) and heavy spatfalls could be obtained on shells held in floating trays. If such shells were later spread on cleared ground it is probable that the cost of rearing the brood might be considerably reduced.

Summary.

1. The setting process of larvae of *Ostrea edulis* is described, and proves to be strikingly similar to that of larvae of *Ostrea virginica* as described by Prytherch (1934).

The fully developed larvae swim with the foot more or less protruding between the valves, adjacent to the velum and, on coming into contact with solid objects, adhere and crawl by means of the foot. This crawling phase always precedes setting and may be prolonged.

When about to set larvae move backwards and forwards over a very limited area and finally come to rest and set with the left valve undermost. During the final stages of setting the larval foot changes in shape becoming shorter and stouter. Fixation is effected by a cement secreted by the byssus gland.

If no suitable surface for attachment is available, setting and metamorphosis can be delayed, probably for several days, increasing the chances of survival.

2. Experiments made in the oyster-breeding tanks at Conway, North Wales, with slates held at different angles show that the greatest intensity of setting occurs on the under surface of horizontal objects, and that the intensity of setting decreases as the angle of the surface to the horizontal increases, resulting in a minimum intensity of setting on vertical surfaces.

It is suggested that the swimming position of the larva with the foot upwards, and the observed limitation of larval swimming to vertical movements only are not sufficient to explain the large differences in catching power between different angles of surface. There may well be an active selection of angle of surface by the crawling larva.

On an inclined or vertical surface the larvae tend to crawl upwards against gravity; this habit may have considerable survival value.

On an inclined or vertical surface the majority of the larvae set with the dorsal margin, i.e., the hinge, uppermost.

3. Oyster larvae attach themselves most frequently in shaded situations during daylight, due it is believed to a negative light reaction on the part of the crawling larva. The same situations are not more favourable during darkness.

The general intensity of setting decreases during the hours of darkness.

4. The intensity of setting near the water surface in the tanks at Conway is very much higher during both day and night than at mid-depth or near the bottom. During daylight the intensity of setting is greater at mid-depth than near the bottom, while during darkness there is no apparent difference; this is probably due to a decrease in the swimming activity of the larvae during darkness.

5. It is suggested that on many oyster beds the scarcity of clean surfaces for the attachment of larvae at the proper time and in the proper place may prove to be one of the main causes of the poor spatfalls experienced in recent years.

The possibility of taking advantage of the demonstrated high intensity of setting near the water surface by using floats containing shell cultch for collecting spat, particularly on natural beds, is considered, and it is suggested that in this way a reduction in the cost of rearing native brood oysters might be effected.

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Letter to the Editor.

IN einem Artikel dieser Zeitschrift[1]) gab ich die Ergebnisse einer gleichzeitigen Bestimmung der Planktonmenge durch Netzfänge und durch Sedimentation und machte darauf aufmerksom, dass es eine recht anfechtbare Arbeitshypothese sei zu glauben, dass man durch Netzfänge relative, vergleichbare Werte der Phytoplanktonmenge erhalten kann. Ich zeigte z.B., dass zwei Stationen, die beide nach den Sedimentierproben reich an Phytoplankton waren, nach der Netzprobe grosse Unterschiede aufwiesen: die eine Probe war sehr reich, die andere dagegen ausserordentlich arm. Es geht nämlich nicht nur das ganze sogenannte "Nannoplankton" völlig durch die Maschen der Netze, sondern auch eine sehr grosse Anzahl der "Mikroplanktonten", die in einigen Fällen recht gut vom Netz erfasst werden, in anderen Fällen jedoch fast völlig durch die Maschen gehen. Dies ist vor allem eine Folge der grossen Variabilität in der Grösse sowohl der einzelnen Zellen wie auch der Kolonien.

Professor Hentschel, der in den letzten Jahren mit einer der Netzmethode ähnlichen Methode gearbeitet hat, hat im vorigen Heft dieser Zeitschrift einen Artikel[2]) geschrieben, dessen Résumé lautet: "Steemann Nielsen's objections to the employment of samples taken by net, or other forms of strainer, for quantitative estimation of phytoplankton cannot be upheld, the argument being that his criticism springs from an erroneous conception of the aim of these methods."

Es ist mir völlig unverständlich, wie Hentschel zu diesem allgemeinen Schluss kommt. Man muss wohl annehmen, dass er meint, meine Arbeit sei ausschliesslich eine Kritik seiner Arbeitsmethoden. Er kann doch nicht bestreiten, dass in neuerer Zeit von anderen Seiten, z.B. der "Discovery" Expedition, quantitative Untersuchungen mit dem Netz vorgenommen sind, um die Phytoplanktonproduktion zu bestimmen.

Hentschel bestreitet, dass seine eigenen Untersuchungen als Ziel die Kenntnis der Produktivität des Meeres haben. Er schreibt (Seite 305): "Steemann Nielsen prüft meine Methodik nicht unter dem Gesichtspunkt ob sie für diese meine Zwecke geeignet sei, sondern unter dem, ob Aufgaben, wie er sie sich gestellt hat, Untersuchungen über die Produktivität des Meeres, damit ausführbar seien".

Ich muss gestehen, dass ich aus Hentschels früheren Aufsätzen

[1]) E. Steemann Nielsen: Über die Anwendung von Netzfängen bei quantitativen Phytoplanktonuntersuchungen, Journal du Conseil, XIII,2. 1938.

[2]) Ernst Hentschel: Über quantitative Seihmethoden in der Planktonforschung. Journal du Conseil, XIII,3. 1938.

über seine Methoden die Auffassung bekommen hatte, dass dies auch sein Ziel sei. Er schreibt z.B., Hentschel 1938, a,[3]) S. 69: "Unsere heutigen Vorstellungen vom Leben des Planktons sind durchdrungen von dem Produktionsgedanken. Man wird demgemäss auch bei geographischen Betrachtungen nach Darstellungen fragen, die diesem Gedanken gerecht werden, nach Karten, die irgendwie die Unterschiede in der Produktion der Meeresgebiete zum Ausdruck bringen."

Dies ist also nach Hentschel, 1938 b, doch nicht der Fall. Was er aber dann durch seine Untersuchungen erreichen will, ist mir unklar; denn die geographische Verbreitung der einzelnen Arten hat, wie Hentschel so oft betont, nicht sein Interesse. Was soll man mit quantitativen Daten über die Gesamtphytoplanktonten einer bestimmten Grössenordnung aufstellen, wenn diese Phytoplanktonten nicht repräsentativ für das ganze Phytoplankton sind? Ökologisch-biologische Tatsachen sind nicht aus solchen Daten herauszulesen. Wenn geographische Verbreitungsverhältnisse ökologisch-biologisch ausgenutzt werden sollen, gilt der — *sit venia verbo* — "kategorische Imperativ": Untersuche die Verbreitung der kleinsten systematischen Einheiten. Wie Rensch[4]), 1934, in seinen Maximen schreibt: "Der merkwürdig häufig unternommene Versuch, die gleichen Resultate auf Grund allgemeinbiologischer Fragestellungen und ohne systematische Arbeit erlangen zu wollen, ist wegen seiner falschen Beurteilung von Voraussetzung und Folge zum Scheitern verurteilt".

Zum Schluss muss ich protestieren gegen die "recht bedenklichen Entstellungen und Verzerrungen" — um Hentschels Ausdruck zu benutzen —, die mein Artikel in seinem Aufsatz erfährt. Es kommt z.B. schon in den ersten Sätzen zum Ausdruck, wo Hentschel schreibt: "Vor nunmehr 36 Jahren hat Lohmann mit grosser Sorgfalt den Nachweis geführt, dass selbst die feinsten Planktonnetze nicht im Stande sind, das feinste Plankton zu fangen. Diese Erkenntnis hat Steemann Nielsen jetzt auf Grund einiger eigenen Beobachtungen neu vorgetragen". Nein, das habe ich nicht. Ich habe gezeigt, dass das Verhältnis Netzplankton: Vollplankton ausserordentlich variabel ist, und dass nur ganz wenige Phytoplanktonarten der "Mikrogruppe" immer quantitativ vom Netz erfasst werden. Dies ist, kann man leider sagen, keine Neuvortragung; denn bis jetzt hatte merkwürdigerweise niemand die Sache untersucht.

Kritik der Methoden ist ein für die Förderung der Wissenschaft nötiger Faktor — und warum unangenehm? — in 25 Jahren sind doch die meisten Methoden bei einer im Pubertätsalter sich befindenden Wissenschaft wie der Planktonforschung längst ein verlassenes Stadium. Auch die Utermöhlsche Sedimentiermethode wird gewiss einen Ablöser finden.

E. Steemann Nielsen.

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[3]) E. Hentschel: Über die Herstellung von Planktonkarten des Nordatlantischen Ozeans. Rapports et Proces-Verbaux, CVII, III, 1938.

[4]) B. Rensch: Kurze Anweisung für zoologisch-systematische Studien. Leipzig 1934.

Essay Review.

By

B. Storrow.

A. C. Stephen. "Temperature and the Incidence of Certain Species in Western European Waters in 1932—1934."
"Production of Large Broods in Certain Marine Lamellibranchs with a possible relation to weather conditions."
Journ. Animal Ecol., Vol. 7, No. 1, pp. 125—9; pp. 130—43, 6 figs. London 1938.

The two papers by Dr. A. C. Stephen here reviewed are of more than passing interest. That dealing with the production and survival of broods of *Tellina* is an example of what can be done by an enthusiastic naturalist who is prepared to give continuous though intermittent effort to the study of an ecological problem in a small area. The other, dealing with the incidence of species in European waters, is an indication of the desire of many of us to find some broad and general cause for change, and the period considered is that of the recent Atlantic activity.

In dealing with changes in a small area it is no uncommon thing to find that one species behaves differently from another. This difference in specific behaviour is well known amongst farmers and gardeners, and anglers are quite familiar with it in connexion with numbers of salmon and sea-trout. It is neither new nor strange, but it has never been explained.

Changes in the occurrence of plankton organisms, whales, dolphins, fish, cuttlefish and even the Clyde fauna are linked up with the *Zostera* changes and air temperature changes on both sides of the Atlantic. It is suggested that all these are associated with a general warming up of the Atlantic and a greater northerly flow of Atlantic water of southern origin. There is also a possibility that there have been somewhat similar phenomena in the North Pacific and in the waters about New Zealand.

Taken together these two papers are of great interest. They indicate a growing tendency towards trying out the possibility of putting local

fluctuations into terms of much wider and more general periods of change and, also, a consideration of means by which we can reach conclusions as to a probable cause.

It is many years since attention was drawn to the possibility of the circulation of the South Atlantic having an effect on conditions in the North Atlantic, and it appears reasonable to suppose that the cause, influencing the circulation of the Atlantic as a whole, would be unable to act without having some effect on the other oceans. There is also a great deal of scattered data which suggests that fluctuations occur simultaneously on both sides of the Atlantic and, also, that they may be complementary. In the same way as we have suggestions that the air temperatures of north-west Europe may increase while those of South America are decreasing — probably because of the relation of the axis of the South Equatorial current to Cape San Roque and the influence of the high pressure area of the South Atlantic — so we have suggestions that southerly fish may move northwards along the European seabord at the same time as fish are retreating southwards along the North American coast.

The influence of the Labrador current appears to have been responsible for this southerly retreat of fish during part of the nineteenth century, but the flow of water from the Arctic shows considerable variation. The beginnings of recent Atlantic activity were soon followed by a strengthening of the Labrador current, in 1932, but it weakened considerably along the Newfoundland coast in the following years, and it was not until the autumn of 1934 that there were indications of Arctic water making its way south along the Newfoundland coast in increased quantity. The incidence of adult fish and larval stages about Iceland suggests little flow of Arctic water through Denmark Strait, and points to there being a general northerly extension of warm conditions from Newfoundland to Iceland at the same time as warm water was influencing the northern North Sea. It is difficult to say whether the rebound from the Arctic commenced from west or east, or whether it was general. It becomes much more difficult, however, when we leave these broad and general ideas and try to establish a chain of events leading to fluctuations in areas much bigger than the Clyde.

While the coincidence between broods of *Tellina tenuis* and air temperatures inclines us to think we are looking at cause and effect, the broods of 1930, 1933, and 1936 suggest that these may have some connexion with the beginning, the maximum, and the end of the most recent period of Atlantic activity. The brood of 1926 brings to mind the beginning of the previous period of Atlantic activity. At once other things force themselves upon us. The Atlantic activity about 1926 may or may not have been the same as that of recent years, and there is considerable doubt about this sameness. Further, the end of the recent period of Atlantic activity was associated with a southerly extension of the influence of the Norwegian Sea and, also, with a strengthening of the Labrador current. While the Labrador current

appears to be too far away to influence the Clyde area, the Norwegian Sea had an effect on circulation along the west coast of Scotland by damming and splitting the flow of the Atlantic in 1935.

Apart from uncertainty as to how and why an increased flow of Atlantic water, round the north of Scotland, is associated with variation in the amount and direction of the flow into the southern North Sea, through the Straits of Dover, there are several other phenomena which are difficult to understand. In 1932, Atlantic plankton was taken over Bressay Shoal and northern North Sea plankton was carried south-east almost to Sylt. In 1933, Atlantic plankton was taken as far south as Aberdeen and drift-bottles travelled the North Sea to the coasts of Norfolk and Suffolk. Again, in 1934, the Atlantic flow was more easterly than southerly — few drift-bottles reached the English coast — and there was a secondary maximum of Atlantic flow in August followed by a reversal of currents off the east coast of Scotland. After this and with a southerly extension of the Norwegian Sea the flow maximum became later, being in the latter half of June in 1935 and in late July and August in 1936. Associated with the combined influence of the Norwegian Sea and the Atlantic in 1936 there were low temperatures in May and high temperatures in autumn. The change amounted to a change of seasons — to summer lasting until October and to autumn being continued to mid-December.

Not only are there differences in the amount of Atlantic water making its way into the northern North Sea by way of the north of Scotland, but there are considerable differences in the direction of this flow and the time when it reaches its maximum. With variations in the distribution of plankton organisms and the apparent path of drift-bottles there is bound to have been considerable change in the distribution of larval and post-larval fish and, in some cases, we know definitely that this was so. We can assume that this will have some effect on the distribution of adults and commercial catches unless some compensatory active migrations are made. Changes in the time of maximum flow suggest that currents, salinities, and temperatures are acting on ripening fish in one year and on spent fish in another year. In other words, the maximum Atlantic flow is probably exerting its greatest influence on the fish when they are making two totally different migrations — ripening fish to or towards the spawning grounds; spent fish to the feeding grounds. The probable effect of seasonal change in sea temperatures is pure conjecture. Low spring temperatures coincide with spawning or spent conditions. What effect, if any, have a prolonged summer and autumn on the growth of fish and the development of the gonads for next spawning season? It may be that the change of seasons in 1936 was responsible for the abnormal growth made by some herrings in that year, for such herrings having marked scales. But all herrings did not make abnormal growth in that year and, in 1937, the normal and abnormal were mixed together off the Northumberland coast.

During the present season, 1938, the salmon catch in the Tyne Fishery District has been the worst on record. In 1937 the catch was about one-seventh of that for the previous season. This marked decrease can be associated with the hydrographic changes broadly and inadequately outlined above and with the appearance off the Northumberland coast of a mixture of rare or comparatively rare fish. This mixture suggests that some fish had entered the North Sea with warm Atlantic water and had retreated southwards before the advance of colder conditions which brought northern fish into Northumberland waters. Neglecting the freshwater life of the salmon and thinking of it in terms of its sea life only, the next obvious step is to ascertain what catches have been made in other districts and countries. These facts are difficult, if not impossible, to obtain. Before arriving at any conclusion as to the probable cause of such a marked change in the produce of any fishery we must have data from other fisheries, and these data should refer, so far as is possible, to the area in which the fish is distributed. In addition as many facts as possible concerning the age, size, and quality of the fish must be taken into account.

There was a time when I had read every book and paper in our library. Now I look at piles of papers which I have not read and can never hope to read. In pessimistic moments I have concluded that we are in danger of being smothered with our own excreta. Were these non-read papers only those which can be termed academic it would be another matter, but there are papers included which deal with commercial fish and fisheries and which must be read and digested before fluctuations can be studied. The same applies to works and papers on hydrography and plankton. During post-war years there has been a great deal of work done: much of it is to be admired and we know vastly more about our fisheries than we did a quarter of a century ago. But we are hindered in our progress by the amount of knowledge we have obtained and by its disordered state. We hesitate to generalize, well knowing we have not a full knowledge of ascertained fact.

To realize the position is a beginning, but to escape from it is another matter, and it is doubtful if one man alone can find a solution. It is easy to suggest that all available facts relating to commercial fish, hydrography, and plankton should be assembled together by the experts of various countries, and that someone should be delegated to bring these together as a connected whole. It is far from easy to make a plan of campaign. Perhaps one of the greatest difficulties will be to find a balance between permanence and change. Our fisheries are mostly permanent, at least over short periods, but anyone who has examined the fish from one fishery over a number of years must have been impressed by the amount of change, not only in yield but in age and quality. Both hydrography and plankton also present this problem of permanence and change. While we must think of mean conditions we must try to find the value of departures from the mean,

and the quantity of the plankton must not be separated altogether from its quality.

Having recognized this fundamental difficulty, which is neither more nor less than the paradox presented by life, we must consider the period to be dealt with first. The changes since 1930 will occupy a great deal of time and call for much application and effort. But to restrict our efforts thus would leave us desirous of a wider conception of the changes about 1928, and also about the changes which preceded the influx of fish into the waters of West Greenland. It does not appear desirable to make the period to be summarized any shorter than that of post-war years, but ways and means will have to govern the extent of the effort made. There is one thing which appears most certain and that is until this work has been done we will not be able to progress. Further, the longer the attempt is postponed the greater will be the effort required. In addition, it is doubtful if we will be able to justify our existence unless the facts we have discovered are made available for use. It may be, after we comprehend more fully the fluctuations of recent years, that we will be able to appreciate better the changes of last century. The seventies of last century appear to have a remarkable significance, and fluctuations about 1800 are associated with violent departures from the mean of winter air temperatures of Stockholm, a disappearance of much ice from the Arctic and an epidemic of salmon legislation.

There are two other things which, sooner or later, will compel attention. The more pressing of these is the use of meteorological data in connexion with the findings of hydrography. The disregard of the connexion between atmospheric and oceanic circulation can have only one result. It is becoming more and more evident that variations in atmospheric pressure gradients are associated with changes in our fisheries and with the distribution of larval and post-larval stages. The happenings about 1921 suggest that atmospheric pressure alone, without winds, may have a very definite connexion with a northerly spread of warm Atlantic surface water. The conditions of the spring of this year were so abnormal that they can hardly have been without effect on the waters of our seas and oceans. To the best of my knowledge no account of these conditions is available for the consideration of those engaged in fishery investigations, and most of us are unable to deal satisfactorily with such a matter. The aid of the expert in meteorology is needed, and at least one trained meteorologist, perhaps more, should be connected with fishery investigations, either as a member of staff or attached.

The other matter deals with changes in the fish and changes in its environment. The visible reactions of fish to changes in environment are being pursued, and such work appears to be the only method of finding a measure, without which desired conclusions cannot be reached. There are other reactions associated with environment and about them we know nothing. During the period of Atlantic activity of 1921 the herrings from the East Anglian shoals would not respond

properly to salt in the making of Yarmouth Reds. In the following period of Atlantic activity herrings were found in Cornish catches which would not make kippers. It is common knowledge that the fish and crabs from some areas are much better eating than those from others. In other words, there are physiological problems associated with environment. This is a period when physiology and experimental zoology are both highly fashionable. It may be possible to avail ourselves of these fashions.

At the present time there is a great deal of faunistic and ecological work being done by our colleges and universities. The full value of this work cannot be obtained unless it is continuous, gives records of both permanence and change, and attempts to discover some cause for its findings. Whatever may be the approach, environment must be associated with the organism, and the environment cannot be dissociated from the influence of oceanic and atmospheric circulation.

The greatest ecological work being done is that under the direction of the International Council for the Exploration of the Sea. In duration, extent, and effort it is beyond all others. The importance of the work arises from its connexion with commercial species, of a distinct economic value apart from academic interest. Combined with the efforts made on the American coast we have biological investigations such as have never before been attempted and their importance is mainly in their utility. The experiences of life demonstrate that nature is a whole and that the pursuit of utilitarian objects alone does not give all we desire. It is evident also that ascertained fact does not serve its purpose until it is made available, becomes part of the general stock of knowledge and is passed on. Further, the tempering of curiosity with utility is compelled by economic circumstances and is for the good. It is reasonable to assume, once we have put fishery investigations into a condensed and usable form, that they will be used for teaching purposes and, by showing the importance of utility, influence the work of our academic brethren. They can be expected to make considerable additions to the study of fluctuations in general. And the study of fluctuations is still the most important thing in fishery investigations.

I am informed that hydrographic data are being examined and will be reported upon in due course. The nature of this report will determine how far we can apply the findings to our own individual problems, and to what extent it is possible to trace the influence of wide hydrographic change to change in narrow waters. By itself such a report will not have anything like the value it would have were it associated with similar reports on fisheries and plankton.

Reviews.

P. Gjessing, E. Steemann Nielsen, E. Bertelsen og **H. Thomsen.** "Beretning om M/S 'Thor's' Havundersøgelsestogt 1935." Publ. om Østgrønland, No. 5, S. 130, Illustrat., Planer og Kort. København, 1937.

This is the fifth of a series of splendidly produced volumes, surpassed in editorial refinement and costliness only by the sumptuous folios describing the results of the scientific voyages of S.A. the Prince of Monaco. It contains the narrative of the adventurous, may be even foolhardy, voyage in the 40-foot smack "Thor" to Iceland and E. Greenland of the four above-named authors and a crew of four, including the young wife of the leader and skipper, Mr. Gjessing.

A large number of fine photographs illustrate the places visited and the incidents of the voyage while a number of large folding plans show the itineraries. The research work comprised oceanography (21 stations of which 17 were in or near Lindenows fjord in E. Greenland and at Iceland), bottom sampling in Lindenows fjord and Isafjord, phytoplankton growth and light-penetration studies near Reykjavik, and shore collection. The narrative is detailed, and all operations and observations are described very fully. The report is concluded by a set of six landfall sketches by Mr. Gjessing.

O. Sund.

G. Dietrich. I. "Die Lage der Meeresoberfläche im Druckfeld von Ozean und Atmosphäre usw." II. "Über Bewegung und Herkunft des Golfstromwassers." Veröff. Inst. Meeresk., N. F., Reihe A, H. 33, S. 91, 45 Abb. Berlin, 1937.

I. The main result of this paper is a chart of the topography of the sea surface for the Gulf of Mexico and for the Gulf Stream with its environs as far as the longitude of Nova Scotia. This is the first such chart published for this region, except Jacobsen's for the North Atlantic which appeared in 1929 (The Danish "Dana"-expeditions 1920—22, No. 3). Dietrich's chart discloses four distinct regions of high elevation of the sea surface placed symmetrically within the Gulf of Mexico, each corresponding to an anticyclonic eddy. Only the south-eastern eddy, the largest, is filled in the upper few hundred metres with water direct from the Yucatan Channel. The water for the Florida Current is supplied by two routes, one around this eddy, the other skirting the north-west coast of Cuba. All along the right flank of the Gulf Stream a ridge in the sea surface is shown, which reaches its maximum at longitude 68°W.; here the elevation is about 80 cm. higher than on the left flank of the stream. This ridge calls for a counter-current on its south-eastern slope. Along part of the course the ridge is

flanked in turn by a trough, calling for a north-east current, so that there are three parallel axes of motion alternating in direction. On the left of the stream north of Cape Hatteras two eddies are shown, the first cyclonic and the second anticyclonic. Jacobsen's chart of course gave less detail, but differed especially in showing a fall of about 70 cm. across the Gulf Stream off Chesapeake Bay as against Dietrich's of 56 cm., in showing no continuous ridge and trough on the right of the stream, and in showing all the water from the Yucatan Channel skirting Cuba to the Straits of Florida.

The elevation of the surface as shown in Dietrich's chart was calculated from the distribution of density in the ocean on the basis that there are no horizontal pressure gradients in the surface of minimum oxygen, which occurs at depths varying geographically between 100 and 1000 metres. This leads in general to a flatter sea surface than computed on the usual basis that horizontal pressure gradients are negligible at a fixed depth of 1000 metres or more, and in particular to the presence of the ridge and trough immediately flanking the Gulf Stream on the right. The validity of this use of the minimum oxygen layer is subject to much doubt (Rossby, 1936, *Papers in Physical Oceanography and Meteorology*, Vol. 5, No. 1; Dietrich, 1937, *Annalen der Hydrographie und Maritimen Meteorologie*, 65: 506—519).

The paper also presents a chart of the topography of the sea surface resulting solely from the mean atmospheric pressure distribution, the effect of which was disregarded in preparing the chart discussed above. The range is only a few centimetres.

The slope of the sea surface along the United States coast found from the density distribution is compared in detail with the differences in elevation of mean sea-level at various ports measured by levelling surveys. The two agree rather closely along the Gulf coast and as far as Cape Hatteras. From Hatteras to Portland, however, the geodetic determination shows a rise of 25 cm., while the oceanographic determination shows no rise. It is stated that this discrepancy lies within the posible error in computing mean sea-level from inhomogeneous oceanographic observations, and that consequently greater weight should be placed on the geodetic results.

R. B. Montgomery.

II. In the preceding paper Dietrich came to the result, from rather unsatisfactory reasoning, that sea level along the axis of the Gulf Stream rises from the Florida Straits to the offing of Nantucket, and that this rise is due to a greater loss of kinetic energy by friction than gain from wind stress. From this there follows a cross-stream circulation, in particular, according to his dynamic calculations, a coastward gradient flow extending from the surface to about 150 metres depth.

This paper emphasizes for the first time the dynamic importance of the secondary O_2-minima, which are tentatively claimed to occur on continuous and rather extensive surfaces. On the ocean side of the Gulf Stream they are found at about 150 and 500 metres, while the principal O_2-minimum occurs at about 900 metres. The secondary minima are supposed to represent regions where renewal by vertical circulation is weakest; thus they locate the axes of the cross-stream and vertical circulation. The following scheme is postulated for the ocean side of the stream:— coastward flow above the upper O_2-minimum descending within the stream and returning offshore between the two secondary minima, and coastward flow above the principal

minimum rising in the stream and also returning offshore between the two secondary minima. This scheme resembles D e f a n t's picture of the vertical and cross-stream circulation in the tropical Atlantic. It is subject to the criticism that the return flow is placed in water of very different density than either of the coastward flows, and it is doubtful whether vertical mixing is sufficiently potent to allow such flow across surfaces of constant potential density.

The cross-stream and vertical circulation are also used to explain (1) the presence and position of the warm water trough within the south-east side of the Gulf Stream, (2) the warm surface-water in the slope-water region north of Cape Hatteras, and particularly (3) the replacement of South Atlantic water in the lower part of the Florida Current by North Atlantic water south of Cape Hatteras.

C. O'D. Iselin.

G. Wüst. "Neuere Auffassungen über das Wesen des Golfstromsystems und die Benennung seiner Glieder." Seewart, H. 10, S. 359—367, 2 Abb., 3 Taf. Hamburg, 1937.

The currents constituting the eastern half of the Gulf Stream System are not exceptionally strong and, therefore, no clear current pattern emerges on the ordinary charts of surface currents. How can the supposedly powerful climatic effect of these north-eastward trending currents be reconciled with their relatively insignificant role on the current charts? In the paper under review W ü s t shows that if the superficial and variable wind current is eliminated, the thermal transport of the gradient current beneath stands out clearly. For this purpose he has plotted the temperature anomalies (departures from 2½° latitudinal normals) at the 200-metre level over the greater part of the North Atlantic Ocean (north of latitude 20°N.). The resulting chart, constructed from more than 3,500 stations, shows a continuous band, having positive anomalies greater than 2°, stretching from the Yucatan Channel to Spitzbergen.

W ü s t considers that this band of relatively high temperatures at the 200-metre level is due both to the horizontal transport of the current and to a cross-circulation with a slight vertical component. There is no doubt that near the surface the warm water lies deepest near the axis of the stream. However, one can argue that the greater turbulence in the current is also partly responsible for the downward transfer of heat. In any case, there is good reason to believe that the axis of flow follows the left edge of the band of positive anomalies and this axis has been shown on a second chart which also illustrates the six subdivisions of the whole Gulf Stream System. No fault can be found with the names and limits suggested for these subdivisions and it is to be hoped that W ü s t's nomenclature will be at once accepted by all oceanographers.

It should be added that W ü s t has here presented a very strong case against one of the assumptions of L e D a n o i s's transgression theory. The Gulf Stream System clearly is an effective agent for the transport of heat towards the north-east. When it can be shown that this movement fluctuates in strength over periods of several years, then it will be possible to judge how important the Gulf Stream System is to the climate of northern Europe.

C. O'D. Iselin.

L. H. N. Cooper. "Oxidation-reduction potential in sea water." Journ. Mar. Biol. Assoc. Vol. XXII, No. 1, pp. 167—176. Plymouth, 1937.

Über das Oxydations-Reduktions-Potential im Seewasser war bisher sehr wenig bekannt. Wegen der biologischen und geologischen Bedeutung des Redoxpotential im Meere hat Cooper diese Grösse einer genaueren theoretischen und experimentellen Untersuchung unterzogen. Das *reversible* Redoxpotential, d.h. das Potential, das eine reversible Sauerstoffelektrode im Seewasser geben würde, lässt sich nicht experimentell messen, da wir keine umkehrbare O_2-Elektrode besitzen. Es lässt sich jedoch aus dem Normalpotential des Sauerstoffs, der O_2- und der OH'-Aktivität berechnen. Es liegt für Seewasser von 10—100 % Sauerstoffsättigung und pH = 8·0 — 8·3 zwischen 0·7 und 0·8 Volt. Wenn man an einem blanken Platindraht das — *irreversible* — Potential im Seewasser misst, so erhält man einen Wert von 0·43 Volt. Für die Organismen wird das Sauerstoffsystem nun weder streng reversibel noch so stark irreversibel sein, wie die Platinelektrode, sondern das Redoxpotential, das biologisch zur Wirkung kommt, wird zwischen diesen beiden, also zwischen 0·43 und 0·75 Volt liegen.

H. W.

L. H. N. Cooper. "On the ratio of nitrogen to phosphorus in the sea." "Redefinition of the anomaly of the nitrate-phosphate ratio." Journ. Mar. Biol. Assoc. Vol. XXII, No. 1, pp. 177—182; Vol. XXIII, No. 1, p. 179. Plymouth, 1937 and 1938.

A. C. Redfield (J. Johnstone Mem. Vol. S. 176—192) hat an Phosphat- und Nitratbestimmungen aus den verschiedensten Meeresgebieten die auffallende Beziehung festgestellt, dass das Verhältnis N:P im Weltmeere etwa dasselbe ist wie in den planktonischen Meeresorganismen und annähernd dem Atomverhältnis 20:1 (Gewichtsverhältnis 9:1) entspricht. Im Einzelnen zeigen sich naturgemäss sowohl im Meere wie beim Plankton Abweichungen von dieser mittleren Beziehung. Cooper verfolgt nun diese Abweichungen (Anomalie des Nitrat-Phosphatverhältnisses) an Hand von Beobachtungen aus dem Englischen Kanal, dem Atlantischen Ozean und vor allem aus dem Mittelmeer. Im ganzen Mittelmeer ist das Verhältnis N:P erheblich grösser als 20, meist 30—50. Das Mittelmeer ist nun überhaupt arm an Nährstoffen, es ist aber an Phosphor bedeutend stärker verarmt als an Stickstoff. Diese negative Anomalie kann sogar im ausfliessenden Unterstrom bis in den Atlantischen Ozean verfolgt werden. Auch zeitlich kann sich das Verhältnis N:P stark ändern: im Englischen Kanal nahm es in der Zeit von 1926—1931 von 12:1 auf 22:1 zu.

In der späteren Ergänzung teilt Cooper mit, dass bei Berücksichtigung des Salzfehlers der Phosphatbestimmungen das Normalverhältnis Nitrat-N: Phosphat-P (in Milligrammatom) = 15:1 wird, in guter Übereinstimmung mit Phosphor- und Stickstoffbestimmungen an Planktonproben bei Plymouth, die ein Verhältnis N:P = 16·3:1 ergaben.

H. W.

L. H. N. Cooper. "The nitrogen cycle in the sea." Journ. Mar. Biol. Assoc. Vol. XXII, No. 1, pp. 183—204, 2 figs. Plymouth, 1937.

Bekanntlich verläuft der Kreislauf des Stickstoffs im Meere über eine Reihe von Zwischenstufen, die im Allgemeinen durch das Schema: Nitrat — Plankton — Aminosäuren — Ammoniak — Nitrit — Nitrat wiedergegeben werden. Das ist jedoch nur eine grobe Vereinfachung, und Cooper hat es unternommen, den gesamten Stickstoff-Kreislauf in allen seinen einzelnen

möglichen Reaktionen auf Grund des heute vorliegenden Beobachtungsmaterials zu diskutieren. Dabei wird weitgehend von der Thermodynamik Gebrauch gemacht. Es wird u.a. die Bildung von Alkylaminen, von Harnstoff und Ammoniumcyanat, von Aminosäuren und von Hyponitrit, die Oxydation von Ammoniak zu Nitrit auf photochemischem, chemischem und bakteriellem Wege, von Nitrit zu Nitrat, sowie die Fixierung des atmosphärischen Stickstoffs und der umgekehrte Vorgang der Denitrifizierung behandelt. Von den Ergebnissen sei erwähnt, dass durch Reaktion von Nitrit mit Aminosäuren kein Stickstoffverlust entstehen kann, dass Ammoniak- und Nitrit-Oxydation auch fern vom Meeresboden stattfindet, dass Hyponitrit als Zwischenprodukt bei der Oxydation von Ammoniak auftreten muss, dass schliesslich eine Reduktion von Nitrat zu Nitrit durchaus möglich ist. Die Untersuchung Cooper's bildet eine ausgezeichnete Grundlage für alle weiteren Arbeiten auf diesem Gebiet. *H. W.*

R. P. Cowles and **C. E. Brambel.** "Photo-electric determination of Phosphorus and Arsenic in the same sample of Estuarine water." Internat. Rev. d. ges. Hydrobiol. u. Hydrogr. B. 36, H. 3/4, S. 325—335, 2 Abb. Leipzig, 1938.

Zur photoelektrischen Bestimmung von Arsen und Phosphor wird die bekannte Molybdänblaumethode benutzt. Die Farbstärke wird mit einer Photozelle unter Vorschaltung eines roten Lichtfilters gemessen. Bemerkenswert ist das elegante Verfahren der Verfasser, Phosphor und Arsen in einer Wasserprobe zu bestimmen, das auf dem Prinzip beruht, dass die Phosphorfarbe sehr schnell, die Arsenfarbe aber erst nach etwa 10 Minuten erscheint. Es wird demnach nach Zusatz der Reagentien einmal sofort (P-Wert) und ein zweites Mal nach Erreichung der maximalen Farbtiefe (P- + As-Wert) photometriert, und es werden dann die beiden Ablesungen auf Grund von Eichkurven ausgewertet. *H. W.*

H. W. Harvey. "The supply of iron to diatoms." Journ. Mar. Biol. Assoc. Vol. XXII, No. 1, pp. 205—219, 2 figs. Plymouth, 1937.

Zur Prüfung der Vermutung Grans, dass Eisen für das Phytoplankton zum Minimumfaktor werden kann, bedarf es der Kenntnis der Formen, in denen das Eisen im Seewasser vorkommt, ferner der Kenntnis des Mechanismus der Eisenzufuhr zur Planktonzelle. Aufbauend auf den Befunden von L. H. N. Cooper (Proc. Roy. Soc. B. *118,* 419; ibid. *124,* 299) kommt Harvey zu dem Schluss, dass das im wahren Lösungsgleichgewicht befindliche Eisen bei weitem nicht ausreicht, um den Eisenbedarf der Diatomeen zu decken. Es bleibt für diese somit nur die Möglichkeit einer Verwertung vom kolloidalen Eisenhydroxyd nach Adsorption an die Zellwand. Sowohl für die Adsorption wie für die Aufnahme des Eisens durch die Zellen konnten experimentelle Beweise an Kulturen von Nitzschia gebracht werden. Für 3×10^{12} Zellen *Nitzschia closterium minutissima* wird weniger als 1 mg. Eisen benötigt, während der Phosphorbedarf 175 mg. P beträgt. Diese Diatomee braucht also nur 1/175 des Phosphors an Eisen, bedeutend weniger als man nach den Analysen von Diatomeen aus dem Meere erwarten sollte, bei denen der Eisengehalt oft grösser ist als der Phosphorgehalt. Das an die Zellwand adsorbierte Eisenhydroxyd wird in irgend einer Weise in Lösung gebracht, sodass es in die Zellen hineindiffundieren kann.

H. W.

H. W. Harvey. "Note on colloidal ferric hydroxide in sea water." Journ. Mar. Biol. Assoc. Vol. XXII, No. 1, pp. 221—225. Plymouth, 1937.

Die bemerkenswerte Tatsache, dass im Ozean das kolloide Eisenhydroxyd nicht ausflockt und ausfällt, lässt sich nach Harvey 1. durch die sehr niedrige Konzentration, 2. durch die Wirkung von Schutzkolloiden erklären. Versuche zeigten, dass die Ausflockung eines Eisenhydroxyd-Sols sehr stark von der Konzentration abhängt, und dass z. B. ein Sol von 300—500 mg. Fe/cbm. im Seewasser tagelang beständig ist. Anwesenheit von Gummiarabikum oder Stärke erhöhen die Beständigkeit noch weiter in starkem Masse. Dagegen hatten Humussäure, Lignin und Lignokaseinate keine erhebliche Schutzwirkung. Es ist daher kaum anzunehmen, dass das Eisen, wie Waksman vermutet, im Seewasser an diese Säuren gebunden vorliegt.

H. W.

G. Ålvik. "Über Lichtabsorption von Wasser und Algen in natürlichen Gewässern." Bergens Museums Årbok 1937, Naturvid. Rek., Nr. 2, S. 1—63, 15 figs. Bergen, 1937.

Employing a number of Schott glass filters and a barrier layer cell, the author has made a series of observations on the extinction and penetration of light in fjord, Poll, and humus waters, and the effect of the light on certain algae. Fairly narrow spectral ranges were obtained by selecting combinations of filters, such that differences in results obtained with combinations enabled the author to calculate the effect of a single narrow band. The total spectral range studied extended from 4000 Å to 7200 Å by steps of approximately 1000 Å — the smallest step being 450 Å.

The light sensitive cell was mounted in the usual manner and the current produced by the radiation was measured by means of a galvanometer. Some treatment is given of the changing composition of natural light with depth inasmuch as it affects the transmission band of the filter combination and the spectral response of the cell. The author discusses such sources of error as the shading produced by the ship, lack of simultaneity in measurements, variations in the composition and intensity of the incident light, galvanometer characteristics and uncertainties in depth caused by expansibility of the cable. Of these, the latter is certainly negligible in comparison with the others in field observations. It is very unfortunate that the author was not equipped with a surface photometer as variations in the surface light may be of considerable importance. A surface photometer should be provided with the same combination of filters that are being used in the subsurface photometer.

In the discussion of the light absorption of algae, no consideration was given to the fact that many red algae grow in the littoral zone as well as at depths of 7 to 10 fathoms or more. Any explanation of the use of light energy by red algae should consider the light conditions at all depths and must include algae which are exposed to air at low tide as well as those growing at depths where the light is mainly in the green region of the spectrum. The actual reflection, transmission, absorption, and dispersion within the tissues of the plants should be considered. Conclusions should not be drawn from the absorption curves of algal pigments dissolved in water, methyl alcohol, carbon bisulphide, and other solvents unless confirmed by absorption in the thallus of the plant itself. In such measurements careful

distinction should be made between light absorbed by the cells of the thallus and light dispersed within the thallus. It is unfortunate that the author did not include objective considerations of available data.

C. L. U.

N. Frost. "The Genus *Ceratium* and its Use as an Indicator of Hydrographic Conditions in Newfoundland Waters." Research Bull. No. 5, Dep. of Nat. Resources Newfoundland, pp. 1—12, 2 figs., 9 charts. St. John's, 1938.

Während der Jahre 1931—1935 wurden jährlich auf 2 Fahrten in der Umgebung Neufundlands, auf der Neufundlandbank und an der Küste von Labrador je etwa 80 Stationen auf Grund von Vertikalzügen mit dem Hjort-Netz bearbeitet. Die der Arbeit beigegebenen Karten zeigen anschaulich für jede Station die Gesamtmenge der Ceratien und das Zahlenverhältnis (prozentual) der 6 vorkommenden Arten. Diese ordnen sich nach zunehmendem Wärmebedürfnis ungefähr in folgender Reihe *C. arcticum, C. longipes, C. fusus, C. tripos, C. macroceros, C. lineatum.* Stark vorherrschend und besonders bezeichnend pflegen die beiden ersten Arten zu sein. Ihre Verbreitung kennzeichnet besonders die wechselnde Ausdehnung des arktischen Wassers (Labrador-Strom). Ihr gegenseitiges Verhältnis inbezug auf das Gesamtgebiet zeigt ausser den jahreszeitlichen Schwankungen auch solche, die sich auf mehrere Jahre ausdehnen. Der Spätsommer (Aug.—Sept.) ist gegenüber dem Frühsommer (Juni—Juli) besonders durch stärkeres Vordringen der südlicheren Formen *C. fusus* und *C. tripos* unterschieden. *C. fusus,* das unter ähnlichen Temperaturbedingungen wie *C. longipes* lebt, scheint doch eine spezifische Beziehung zum atlantischen Wasser zu haben. *C. tripos* scheut arktisches Wasser und wird dadurch zu einer guten Leitform.

Die Arbeit gibt ein besonders günstiges Beispiel zur Charakter- und Leitformenfrage, was teils an den hydrographischen Verhältnissen des Gebiets teils an der Wahl der untersuchten Organismen liegt.

E. H.

Fr. Bernard. "Cycle annuel du nanoplancton à Monaco et à Banyuls: 1. Etude quantitative." Ann. Inst. Océanogr. N. S., T. XVII, Fasc. 6, pp. 349—406, figs. 1—4, graphs 1—21. Paris, 1938.

This piece of work was undertaken primarily to fill up the rather serious gaps which exist in our knowledge of the nannoplankton and chemistry of the Mediterranean. Two stations, of dissimilar character, were selected, the one at Monaco, the other at Banyuls. Forty-nine series of collections were made at the former station during 1937 and thirty-five at the latter. Concentration of phosphate, nitrate, and chloride were regularly determined; that of silicate was discontinued in June when it appeared that not only was the plankton very poor in siliceous organisms, but also that the minimal concentration of silica was in the region of 80 mg. SiO_2 per cubic metre. In addition to measurement of sea temperature, records were available of rainfall and of direction and force of the wind at two shore stations, Monaco and Cap Béar.

The abundance of nannoplankton was expressed in terms of volume. The author points out that a comparison of the productivity of two regions based on numbers of individuals is calculated to give a misleading picture, since a few thousand large Coccolithophores will have the same volume — and hence, presumably, about the same weight of protein, etc. — as several million

small flagellates. To arrive at the volume of nannoplankton, counts were first made, using the inverted microscope technique of Utermöhl; the enumerated totals were then multiplied by factors representing the mean determined volume of an individual of each class of organism.

The most striking differences between the general environmental conditions at the two stations may be briefly summarized as follows:—

Rainfall. Annual mean, mm. per annum.
Monaco 910 — Banyuls (Cap Béar) 542

Wind. Force, mean velocity per day, metres per second.
Monaco 1·7 — Banyuls (Cap Béar) 7·2

Wind. Direction, prevalence of onshore or offshore winds.
Monaco No marked predominance of either. — Banyuls (Cap Béar) Offshore winds (chiefly NW.) dominant.

Sea Temperature. At depth of 10 metres, annual mean, 1937.
Monaco 17·95°C. — Banyuls 16·91°C.

Slope of Sea Bottom, Offshore.
Monaco Shelving steeply to depth of over 1600 m., 13 km. from shore. — Banyuls Very gentle slope, only 70 m. at about 9 km. from shore.

Concentration of Nutrient Salts. At depth of 10 metres, annual mean.

Phosphate.	*Nitrate.*
Monaco 0·41 mg. P_2O_5/m.^{3}	Monaco 122 mg. N_2/m.^{3}
Banyuls 0·80 mg. P_2O_5/m.^{3}	Banyuls 103 mg. N_2/m.^{3}

Volume of Nannoplankton. Annual mean, cmm./litre.
Monaco 0·227 — Banyuls 0·750

Of the various factors which might affect the production of nannoplankton in the upper layers (10—50 m.) and which have been analysed in the present report, the author believes the most important to be the wind. Periods of high plankton production occurred almost always just after a prolonged spell of strong offshore winds. The effect of the wind is indirect; it acts by setting up surface currents, which carry out to sea substances in solution from the land. A second effect is, probably, the establishment of deep counter currents, which for their part, bring in nutrient salts accumulated in the deep water. A further point of some interest was the abundance of nannoplankton in deep water. In March, for instance, a volume equivalent to about 0·25 cmm./litre was found at a depth of 1000 metres at Monaco. Moreover, the mean catch for all collections at 1000 m. was 0·15 cmm./litre, with that at the surface, which incidentally was the largest, only 0·10 cmm./litre greater.

In Chapter VI, pp. 388—399, the author reviews briefly our present knowledge of the nitrogen and phosphorus cycles in the sea. It is not possible in a short review such as this to do justice to a section which deserves careful study. Bernard points out that there is a general similarity between the nitrogen and phosphate cycles, suggesting that similar agencies may be at work in both cases. Little experimental work has been done so far on the phosphorus cycle, but it looks as if phosphoric acids are liberated following the breakdown of organic matter rich in phosphorus. Similarly, just as there are "Bactéries dénitrifiantes" so there may be "organismes déphosphatisants". In the latter case, however, the end products will be different. Loss of nitrogen from a system results, presumably, from

the production of gaseous nitrogen; in the case of the phosphorus cycle, it is necessary to postulate the formation of some insoluble compound.

In conclusion, the quantitative results obtained and their full examination in the light of a number of environmental factors make this a valuable contribution to the science of marine biology.

A. C. G.

A. L. Wells. "Some Notes on the Plankton of the Thames Estuary." Journ. Anim. Ecology, Vol. VII, No. 1, pp. 105—124, figs. 1—4. London, 1938.

The author has made a survey of the plankton of the Thames estuary, which is regarded as that area enclosed by a line from Harwich to the North Foreland passing through the "Kentish Knock" lightship. It thus comprises an area in which a number of inshore fisheries are carried on for sprat, whitebait, shrimps, and cockles, and notably the Whitstable oyster. Collections were chiefly made with a small Apstein net, of silk with 60 threads to the inch, streamed in the tide from the extension at the end of the Southend pier, about 1¼ miles from the shore. Samples were taken at intervals of one to three weeks according to the tidal conditions between November 1933 and November 1934, and additional collections were then made at monthly intervals until April 1937. A series of observations made at different states of the tide showed that owing to changes in the speed of the tidal stream the greatest catches were made two hours before high water, and this time was chosen for the routine observations. A diagram is given showing the seasonal occurrence of the more important members of the phytoplankton and zooplankton. The composition of the samples was typical of littoral waters. The most abundant and regular diatom was *Biddulphia sinensis*, the next being *Bellarochia malleus*. *Skeletonema costatum* when present was very abundant but the coarse mesh used is not likely to give reliable data for this diatom. *Acartia clausi* was the commonest copepod, while the medusa *Rathkea octopunctata* was very abundant from March to April. It is interesting to find that *Sagitta elegans* was a constant member of the plankton, though less numerous than *S. setosa*.

This report forms a useful addition to our knowledge of the planktonic fauna of an area that has as yet received little attention.

F. S. R.

S. Å. Waksman and **M. Hotchkiss.** "On the Oxidation of Organic Matter in Marine Sediments by Bacteria." Journ. Mar. Research, Vol. I, No. 2, pp. 101—118, 2 figs. New Haven, Conn., 1938.

The organic content of marine sediments varies considerably with depth, distance from land, etc. The authors suggest that the rate of oxidation of this organic matter by marine bacteria is a measure of its availability to marine life, and proceed to determine the rate at which mud samples from varied localities absorb oxygen from aerated sea water. The samples, obtained as short cores in sterile glass-tubes, were divided into the brownish surface layer, A, 1—2 cm. thick and the darker sub-surface layer, B. The moisture content and N-content having been determined on an aliquot portion, amounts of ca. 1 g. were added to 225 cc. oxygen bottles. These were then filled with aerated sea water "stabilized" by ageing and kept, with appropriate controls, usually immersed at room temperature in the dark for several days. Due to the absorption of iodine by mud it was found necessary to siphon off the superlatent water at the end of an experiment

into another bottle for the oxygen determination by the Winkler method.

Sand, sandy mud, and organic mud treated in this way showed an oxygen consumption after 31 days of 0·44, 1·31, 6·14 cc. O_2 per gramme of dry material respectively, which was related to the organic content: 0·8, 1·46, 5·82 % dry material respectively; calculated as total N × 20. The "chemical" oxygen absorption of sterilized samples was negligible. The surface layer A showed a higher organic content and higher oxygen consumption than the lower layer B. During the experiment an increase followed by a decrease in bacterial numbers was noted in water to which mud had been added. This decrease was not accompanied by a corresponding falling off in oxygen consumption. Frequent shaking of the bottles during the experiment only increased the oxygen consumption by small amounts. The addition of more than 1 g. portions of mud to the bottles reduced the oxygen absorbed per gramme of mud. At 4°, 23°, and 31·5°C. the oxygen consumption of the same sample (0·234 % N.) was 0·62, 1·35, 1·58 c.c. O_2 per gramme of dry material respectively.

Under optimum conditions 1 mg. of organic matter in inshore muds consumed ca. 0·1 c.c. O_2 in 15—30 days. The equivalent amount for oceanic deposits (> 150 m.) was usually $< 0{\cdot}01$ c.c. The higher O_2-consumption in the surface layer, noted above, disappeared in these samples. These amounts are very small compared with the oxygen absorbed by decomposing plankton material. The authors conclude that the organic matter in marine deposits is very resistant to bacterial oxidation, while that in oceanic deposits is the most resistant of all. During the short period of experiment no appreciable amounts of organic N were mineralized. The oxidation was at the expense of the non-nitrogenous constituents.

C. H. M.

H. Thompson. "Annual Report of the Newfoundland Fishery Research Laboratory, 1935." Rep. Newfoundland Fish. Res. Lab., Vol. II, No. 5, pp. 95, 19 figs., 5 charts. Cardiff, 1936.

This short report of 95 pages includes 26 pages of tables; it bears a strong testimony to the organizing ability and leadership of Dr. Harold Thompson, who in five years and with restricted means has performed a truly astounding piece of work in clearing up the most important aspects of questions connected with the fishery possibilities of that country concerned with most fishing in the world, Newfoundland.

The first few pages are devoted to a full, though succinct, review of the Newfoundland fisheries with many practical hints for their improvement based on the experience gained through the five years of work at the fisheries laboratory in Bay Bulls. The work there has had the evaluation of the available resources as a main goal and in this connexion much stress is laid on the variations in the physical conditions of the sea water besides the estimation of the strength of fish stocks. It is seen that the laboratory has explored all possible ways of utilizing the available raw materials and even achieved some progress on the educational side by providing courses in fishery matters as and when requested.

The report also contains short accounts of the hydrographic conditions (by H. Thompson), on plankton (by H. Thompson and Nancy Frost), on the haddock investigations (by H. Thompson). The hydrographic conditions are strange compared to European waters in showing temperatures below freezing point in all Newfoundland waters except on the Grand Bank at depths greater than 10 metres. The plankton results are

of great methodological interest in as far as they show how a single organism can be used as an indication of the relative strengths of the two main water-bodies, the interplay of which have a decisive influence on the fisheries. This organism is *Oikopleura vanhöffeni*, the occurrence of which is discussed at some length. The haddock stock is shown to consist mainly of the year-classes 5—7 while the commonest size is 52 cm., — very different from the North Sea. This fish occurs mainly in "warm" water, 4—7°C. while large catches of cod are often made at half a degree below zero.

A study of the relative productivity of fishing grounds by H. Thompson shows that the Grand Bank seems to be the richest trawling ground known, yielding about 2,850 cwt. per 100 hrs. fishing as compared with 1,625 for the Bear Island area and 100 for the North Sea.

Interesting results are given as to the age-composition of the cod stocks along the coast and of the racial groups met with. It seems from these that the fish on different parts of the coast are of a locally very restricted character. This view is borne out by the tagging of cod, comprising in all the very respectable number of 8,336.

Even the salmon has been the object of intensive study. It is shown, *inter alia*, that the river life of the parr is longer in the northern rivers of the island and Labrador than in any other place, including Finmark and therefore the recruiting power of the stock very low. Good evidence is also provided for the correctness of the supposed dependence of a good run on a high percentage of grilse the previous year.

Appendix A contains particulars of the 123 stations occupied, comprising about 4,000 plankton hauls and trawl hauls. Appendix B gives all the hydrographic data at upwards of 200 observation points (900 single observations) from cruises in March to May on the banks, in June—July round the island and along the edges of the banks, along the Labrador coast, and in August—September the same again, thus repeating the same plan for the fifth year.

Appendix C is an account of lobster investigations by C. C. Whiteley, appendix D an account by Nancy Frost of a further specimen of a giant squid, which is described in detail.

There are 8 clear folding charts of the hydrography and one showing results of the drift-bottle experiments. Six of these were recovered in Europe after 421 to 501 days adrift.

O. S.

R. Kändler. "Untersuchungen über das Laichen des Ostseedorsches im Herbst." Kieler Meeresf., Bd. II, S. 272—292, 2 Abb. Kiel, 1938.

During a cruise in the Baltic in September 1937, the author obtained a remarkably large quantity of cod eggs in the Bornholm and Danzig basins. As many as 183 eggs per m.^{2} were procured. In fact, never before has there been recorded such a large amount of cod eggs in this district. Several earlier investigations have shown that the cod eggs are generally most numerous in June, and no such eggs have ever been recorded in these basins later than August. It is to be noticed, however, that before this cruise took place, no investigation of the presence of cod eggs in this area seems to have been made in September.

Spawning cod have earlier been caught in this part of the Baltic from March to July. In a catch of 76 female cod from the Bornholm basin, 23. September 1937, which the author investigated, 20 individuals were in stage II, 2 in stage IV, 3 in stage V, 2 in stage VI (spawning) and 49 in stage VII (newly spent). According to the author, this catch shows two

fairly distinct groups, the one containing, chiefly, newly spent individuals and the other individuals with gonads in repose.

A comparison between his own and earlier investigations leads the author to the conclusion that the cod in this part of the Baltic has two different spawning periods, one longer in spring and early summer and one shorter in the autumn.

In order to find out if there were any morphological differences between the spring- and autumn-spawning cod, the author placed together the results of his own and earlier vertebrae counts on cod from the Bornholm and Danzig basins.

The average number of vertebrae of cod caught in April 1933 and May 1931 was 52·50 (Bornholm basin 52·45, Danzig basin 52·60), while the corresponding number in September 1937 was only 52·19 (Bornholm basin 52·24, Danzig basin 52·10).

The author divided the cod caught in September 1937 into two groups of which the first contained those individuals with gonads in stages I—II, and the second individuals with gonads in stages III—VII. In the first group the average number of vertebrae was 52·41 and in the second 52·08.

A similar division of the cod caught in May—June 1931 showed that the number of vertebrae of the individuals with gonads in stage I then was 52, while of those belonging to stages III—VII the corresponding number was 52·49. In April 1933 no such difference between the two stage-groups was observed, which in the author's opinion is probably due to the fact that all individuals then, even those in stages I—II, were spring spawners.

Because of these observations the author holds the opinion that in these basins there are two different races of cod to be met with, i.e., spring spawners with a higher (52·5—52·6) and autumn spawners with a lower number of vertebrae (52—52·1).

As no cod eggs have been found during the autumn in the Baltic, west of the island Bornholm, the author states that the cod in that part belong exclusively to the spring spawning race, while both races occur in the Bornholm, Danzig and Gotland basins. As a consequence of his own observations and the fact that the cod in different parts of its area of distribution spawns at different seasons, the author also states that the species *Gadus calarias,* like the herring, is divided into several races.

The investigations dealt with in this treatise are of a very great interest and they constitute a useful contribution to our knowledge of the Baltic cod. Earlier observations by Danish and Swedish biologists have, certainly, shown that the cod in the Baltic is far from homogeneous as regards morphology and spawning habits, but no one before the author has tried to examine this species so narrowly in a limited area during different seasons of the year. The results he has gained are rather remarkable and may serve as a starting point for new investigations of the same kind. One may, doubt, however, if his results are quite so sure and definitive as the author seems to suppose.

Thus it must be considered as a weakness of the argumentation that this is based partly on a comparison of collections made in different years. The author has, certainly, observed a remarkably high number of cod eggs in September 1937, and this number is quite as high or even higher than that observed during spring in some earlier years, but as long as no observations concerning the amount of eggs in other seasons of 1937 are at hand, it is hardly possible to find out if in this particular year there were two different maxima in the numbers of cod eggs. But even if this were so it still remains

to consider whether this was not an exception. It may here be pointed out that cod with gonads in stages V or VI have been found in different localities of the central and southern parts of the Baltic, at nearly all seasons of the year, but hitherto there has been no indication of any distinct increase of spawning individuals at the end of the summer or in the autumn; on the contrary, all observations point to a decrease of the spawning towards the autumn.

Consequently it may be excusable if the author's opinion of the presence of two different and fairly well-defined races will be met with some doubt.

It is certainly quite probable that the observations as to the greater number of vertebrae in the spring spawning than in the autumn spawning cod in the Bornholm and Danzig basins are correct. This fact is of course in itself very interesting. An examination of spawning cod caught during different months of a year may, however, give the result that there are not only two races but a continuous chain of forms with gradually decreasing numbers of vertebrae in correlation to the time of spawning. Several recent investigations seem to indicate that the herring, for instance, does not consist of some few races sharply separated from each other but of a multitude of forms often gradually merging into one another without any distinct breaks in the series. Also, as regards the cod, Johs. Schmidt has shown the close correlation that seems to exist between the number of vertebrae and the temperature of the water, resulting in a gradual increase of the number of vertebrae from south towards north. It may be possible that series of forms arise also inside a limited area if the spawning takes place there during a very long period of the year. The cod in the southern and central parts of the Baltic seem to be a very good object for studying this problem.

Chr. H.

F. N. Clark. "Interseasonal and Intraseasonal Changes in Size of the California Sardine (*Sardinops caerulea*)." Calif. Div. Fish and Game, Fish Bull., No. 47, pp. 28, 11 figs. Sacramento, 1936.

The work on the sardine in California has a double interest for fishery science in general. Firstly, it has been an effort of some magnitude, started with great care after consultation with several scientists, such as W. F. Thompson of Seattle. Secondly, the attempt has been made to acquire the fundamental data of our science in a species in which age-readings are not available. In the sardine of California, age-readings "can be at best but a series of more or less skillfully made arbitrary decisions" (Thompson. J. du Conseil, IV, p. 226). Workers in Europe have something of the same difficulty for cod. Mr. Oscar Sund's methods and conclusions for the Norwegian stock are well known. In the North Sea it was possible to use scales for the first two years of life. The analysis of length-measurements, to which the reviewer was ultimately driven, had, in addition, some help from experience of growth of marked fish and fluctuation in size-categories on the market. Dr. Frances Clark had no such auxiliary data and it is of general interest to examine what results she has been able to achieve from measurements of length alone.

The paper under review gives evidence of a fine piece of work, well conceived and well carried out. The existence of such valuable data has tempted the reviewer into a discussion of methods; for the difficulties which Dr. Clark has encountered are common to most fishery work, in some form or other.

The paper is a sequel to earlier ones, such as No. 31 of the same series, but it has been written so as to be understandable by itself. Since 1919 there has been regular sampling of the catch at canneries, carried out twice a week during the season. Five samples are taken, each of 40 or 50 fish, preferably from different fishing vessels. The fish are caught with purse-seine or similar gear. Body-length is measured from the snout to the base of the tail. This is done at four places on the coast of California, with modification where staff does not permit so many samples. These data are worked up, for various localities and seasons, in the form of diagrams of frequency per cent., at each mm. of body-length.

Dr. Clark is well aware of the disadvantages of percentage curves. For example, she always speaks of the *dominance* of a length-group, not of its strength; no doubt because of the usual difficulty, that the show made by any length-group of fish is dependent on the strength or weakness of other length-groups.

Presumably Dr. Clark has tried ways of overcoming the disadvantage of expressing frequency as a percentage, but has been deterred by the difficulty of finding any precise "weights", to apply as factors, in order to reach a better statement. The same problem occurs in many other cases and the reviewer hopes that even rough methods will not be rejected because they are inexact. For example, the statistics of weight of sardines landed in California are good, so that it might be possible to express the data as length-frequency of the total catch, multiplying the frequency in each sample. or group of samples, by the ratio of the weight of the total catch to the weight of the sample. This would appear to move us one step away from these dangerous percentage frequencies; but it may not be much better. In so far as the market is probably limited by cannery capacity, the expression as total catch may have something of the same fault as before. That is, the entry of a strong group would in itself reduce the catches of weaker groups.

In that case, there is nothing for it but to aim at weighting to give frequency per unit of fishing effort, which would obviously be difficult in this fishery. All vessels are licensed, so that their number is available. In the period since 1919, there have, however, been great changes in size of vessel and in fishing methods. Such things are not included in ordinary fishery statistics. Nevertheless, the reviewer, for his part, would not hesitate to try to collect information for some approximations, from operators in the industry. By now, experienced canners must be able to give a good guess at the percentage increase in catch they would expect on the average, by changing over from a vessel of one size to that of another, or by changing from the primitive "lampara" to the "ring-net", and so on.

The idea has also occurred to the reviewer that data could sometimes be expressed as frequency per unit of money expended. It is sometimes common knowledge how much per day it costs to keep and run each different type of vessel. It is to be remembered that we are only looking for weighting factors, and if these have the correct order of magnitude, we are not likely to be seriously misled by their inaccuracy.

The paper deals with the sardine fishery of various seasons. In the fall the younger adult and adolescent fish are taken, and their length-frequency shows movements from year to year, in position of peaks and depressions, that can be reasonably explained as due to the dominance or relative poverty of different broods, or year-classes. These are particularly well shown up by curves of deviation from the mean frequency, a method which we associate in fishery science with the name of Oscar Sund.

In winter, older fish join the population, making more groups, so that the picture is no longer so clear as for the fishery for the fall. The main groups are, however, clearly shown, and we may accept the interpretation put on Figure 10, in which five dominant groups are recognized, in the fishery from 1919 to 1935.

These groups are designated A, B, C, and so on, in order of their appearance in the diagram, corresponding with groups shown more clearly in the diagrams for the fall fishery. A, B and C contributed clearly to the fishery for at least five years, in every case. Group C, however, only shows up for three years and group E is doubtful after one.

From this reduced apparent survival in recent years, Dr. C l a r k deduces that there is depletion of the stock, and there is very little doubt that she is right. The reviewer, however, would be inclined to base this on considerations other than those adduced. Owing to the lamentable property of percentage frequency diagrams, the extinction of group D in 1932—1933 is aided to some extent by the astonishing contemporary survival of a group called "C?". This seems to reduce the evidential value of D's apparent early extinction. Also, in 1936 it was a little early to base much on the doubtful history of group E. Were it possible to show the same thing with diagrams of frequency per unit of effort, the criticism as to group D could not be made.

Dr. C l a r k's data do seem to indicate depletion by an argument she has not used. As she has written, one sign of depletion is that the later stage of a fishery relies on fewer age-groups than the earlier. In Fig. 9 it looks as if the standard deviation of every season's frequency table, for the eleven seasons from 1924 onwards, will be found to be less than any of the earlier five values of the same statistic. Of course, mere inspection is insufficient to judge this. Workers on the spot may also know reasons why such an argument is invalid.

To return to the point first raised, that is, as to how much has been achieved with data of length alone, it seems that a number of interesting details have been found and two important conclusions established. Firstly, the fishery is supplied by a stock that undergoes major fluctuations every three or four years. Secondly the fishery of the fall, on adolescent and young adult fish, is of different kind from that of the winter, when the older fish are included.

Dr. C l a r k, and others responsible for the programme, are certainly to be congratulated on the results already achieved.

M. G.

W. L. Scofield. "Sardine Oil and Our Troubled Waters." California Fish and Game. Vol. 24, No. 3, pp. 210—223, figs. 74—75. San Francisco, 1938.

The fishery literature is assuming a mass that nearly overpowers the student, and a great deal of it needs the painful reading that statistical evidence demands. By contrast, one welcomes this paper, of which the witty title is not belied: there is further entertainment within.

Apart from jokes, the serious matter is that the use of sardines for oil has encouraged development to the stage where depletion of the stock of fish is considerable and overfishing is, at any rate, imminent. Somehow, the author must convey to the public the danger that is present — the hard, unavoidable and acutely distressing effects on men and trade, when there is overfishing. It is fortunate when the man whose business it is to be the bearer of evil tidings is gifted with a shrewd sense of humour. "... it has

been argued by a few people with no outward sign of jesting that we need not be concerned about our sardine supply, for it will adjust itself at an economic level if left alone. The tragic jest is that our sardine would probably do just that if left alone", that is, if not protected. The reviewer may add that, in his opinion, the "economic level" is the equilibrium represented by the equation:—

$$\text{Average profit} \rightleftharpoons \text{Nil.}$$

No one will regret the trouble of finding and reading the whole paper. A good feature is the collection of 16 important questions and answers about sardines. No. 15 of these questions is, "Is the supply being depleted?". The reply starts "Yes. The first evidences of overfishing ...." and then follow three considerations, each of which is indeed evidence of depletion. The reviewer, however, would not consider any of them to be evidence of overfishing. For many years there have been people, whom the late Professor McIntosh called "Impoverishers", who have used "depletion" and "overfishing" as if they meant the same thing. According to the theory current for bottom-living fish, however, a stock that was not depleted would be *under*fished, the process of continued depletion taking the fishery through the successive stages — underfishing, optimum fishing, overfishing.

A short exposition of the theory of optimum fishing has recently been published[1]), so it may be better to use this opportunity to set out the implications of another view, in which "depletion" and "overfishing" would indeed be synonymous. An extreme form of this view would be that fishing, as an added rate of mortality, must cause continuous depletion of the stock; so that *all* fishing is overfishing. This is not, I think, Dr. Scofield's opinion. An alternative is that some degree of fishing would not be overfishing; but rational fishing. This would be possible if we assume some degree of compensation, due to reduced natural competition. The assumption in this case has to be that rational fishing leaves the same number of fish in the sea that were present in an untouched stock, otherwise there would be depletion. The fishery must, therefore, only take the number of fish annually that could be provided by

(i) Reduction of natural mortality,

(ii) Compensation by increase of recruitment of fish of catchable size.

(i) Reduction of natural mortality, may take place when the enemies of the fish under consideration are also fished hard, so that it might be that the fishery for cod and haddock in the North Sea has allowed the enormous fishery for herring to develop. In addition, there may be elimination of senile and diseased fish. Theoretically (ii), increase of recruitment, might take place owing to elimination of fish that have passed their maximum fertility. Compensation for removal of older spawners might also take place through increase of the growth-rate, if this caused earlier onset of sexual maturity.

So it is not absurd to imagine a fishery without depletion of number of fish in the stock, though the reviewer cannot help thinking that such a fishery would generally be a relatively small one, unless the enemies were fished hard.

But is it equally possible to conceive of a fishery where there is reduction of numbers, but not of the weight of the stock, which is another way of defining "depletion"? The answer seems to be in the negative, except to the very small extent that fish may lose weight of flesh as they grow old.

[1]) Nature, 1938, p. 1143.

The crucial question is about the rate of recruitment. If it is thought that the number of recruits is, in the long run, proportional to the number of the parent spawners, then the theory just set out meets the case. If, on the other hand, it is thought that there is excess of spawn, or compensation in natural mortality of brood, then the theory expounded elsewhere holds, and depletion and overfishing need not be the same thing. Everyone must make their own choice on this point, because there are as yet no data sufficient for a decision.

The underlying anxiety is at any rate completely justified; for it can be shown, on either theory, that any unrestricted fishing naturally leads to overfishing, which either produces the dangerous equilibrium already referred to, or progressively reduces the fishing to nothing.

M. G.

F. Devold. "The North Atlantic Halibut and Net Fishing." Appendix: "The Bottom Temperatures", by **J. Eggvin.** Fiskeridirekt. Skr., Ser. Havunders., Bd. V, Nr. 6, S. 1—68, 30 figs. Bergen, 1938.

This paper makes an important contribution to the life history of the halibut in North Atlantic waters, with special reference to the influence of the net fishing on the stock of halibut; the appendix contains a survey of the bottom temperatures along the Norwegian coasts.

The net fishing showed that great numbers of halibut were present in the deep fjords in north Norway and that fish with running roe and milt were to be found about Christmas. As it appeared that practically all the fish caught in nets had empty stomachs, it is obvious that the halibut only eat very little during the spawning time. The reason why the line fishery is rather poor during winter might, therefore, be sought to some extent in the fact that the large, mature halibut are not inclined to take the bait. In all probability the halibut prefer the deep, comparatively warm bottom-water in the fjords of north Norway as spawning places. The depth at which spawning takes place is 300—700 metres, the temperature being between 6 and 7° C., and at all places where big catches of halibut in spawn are made, there was a soft clay or mud bottom.

Marking of halibut has been carried out on the Bear Island Bank, along the Norwegian coast and near the Faroe Islands. Only comparatively few of the marked fish have been recaught, but the results seem to show that migration from the Bear Island Bank to the Norwegian coast is not uncommon and the author found indications that after spawning in the deep basins of the Norwegian fjords, the halibut leaves the fjords, to return next autumn to the same fjord to spawn again. It is, however, possible to arrive at definite conclusions as to migrations only by marking fish on a large scale, and it is to be hoped that such marking experiments will be carried out in the future.

The age of the halibut netted was determined by means of otoliths, the reading of which has been possible for very large and old halibut, up to an age of about 40 years. There is a great difference in the growth of mature males and females, the males growing much slower than the females, the maximum lengths being about 180 cm. and more than 230 cm. respectively. It is supposed that the greater number of halibut reach maturity at the age of 12—13 years, the average length of males being about 105—110 cm., of females about 135 cm. In this connexion it may be mentioned that a 25-year-old male has an average length of 138 cm., a female of the same age a length of 183 cm.

The method of taking halibut with a special net in deep water in

Norwegian fjords was first started in 1936, and this new way of catching halibut increased the output to so great an extent that it became necessary to safeguard the stock of halibut in Norwegian waters by law. The most important points in the "temporary act for the protection of halibut" are as follows:— 1. minimum size of fish: 50 cm. from tip of the snout to tip of the tail; 2. minimum size of mesh: 3 knots per ell (20·88 cm. between knots); and 3. fishing with nets prohibited in the period from December 15th to February 28th (29th), both days included.

The paper further gives a statistical survey of the catch of halibut in the Bear Island area, in the Barents Sea, along the north-west coast of Norway and in the North Sea. While the total quantity of halibut caught in the Barents Sea has been more or less constant in the years 1928—36 and the trawler's catch per voyage in this area does not point to any decline in the stock, the rarity of large halibut in the trawl catches grew constantly during this period. In all the other areas mentioned there was, however, a constant and rapid decrease in the output of the halibut fishery during the last 8—10 years.

The experience from all places where halibut fishing is carried on tends to show that the stock is easily reduced. D e v o l d gives it as his opinion that the net fishing in the restricted regions where halibut have collected is so effective that the majority of halibut are likely to be caught in a month's time and that it is an urgent necessity to take up the question of protecting the halibut in North Atlantic waters. "The preservation of the halibut stock is to be considered an international question, and it is to be hoped that as many as possible become aware that it is a question which should be urgently handled."

P. Jespersen.

H. Wood. "Movements of Herring in the Northern North Sea." Fisheries, Scotland, Sci. Invest., 1937, No. III, 49 pp., 6 figs., 4 charts. Edinburgh, 1937.

In a paper published in 1931 the author indicated the distribution of the herring shoals in relation to their spawning grounds according to maturity. An examination of the scales was considered inexpedient at that time and it was almost impossible to find a close relationship between the number of scale rings and size. Recent race investigations by the author (1936) have removed this difficulty. It has been proved that the Scottish herring population is not uniform in composition but consists of at least three different stocks with different spawning grounds and spawning seasons and each having a characteristic growth-rate. In the present paper the author has shown that distinctive features in age composition combined with race analysis prove valuable aids in tracing the distribution and movements of the three main race-groups which frequent Scottish waters.

First, the value of scale rings in age analysis has been tested and the results prove that in the case of various groups found in Scottish waters, the scale rings can be accepted as valid for purposes of age determination.

The herring population of the northern North Sea includes spring spawners, Scottish autumn spawners, and southern North Sea late autumn or winter spawners. All of them are led to the northern waters of the North Sea in spring and early summer by the need for food. In May and June these shoals extend their range westwards and until the latter half of July both spring and autumn spawners appear in the catches off the north and east coasts of Shetland. Towards the end of July the adult Scottish autumn spawners move in a southerly direction and become distributed over the

spawning grounds along the Scottish north-east coast. The shoals, after spawning, withdraw rapidly from the coastal grounds and many appear in the trawl catches from the Fladen ground from mid-September until the end of the year. Thereafter contact is lost until drift-net fishing operations commence in the northern North Sea in April. The movement of the adult autumn spawners corresponds with an annual circular movement around the northern North Sea.

In July when the autumn spawners migrate southwards to the coastal spawning grounds, the spring spawners withdraw seawards and rarely make any further contribution to the drift-net catches in Shetland during the rest of the summer. After six or eight weeks they are encountered again in trawl catches from the Fladen ground as maturing fish associated with spent autumn spawners. In January they move off to concentrate on the spawning grounds on the north and west coasts of Shetland and on the Viking bank.

Like the spring spawners, the southern North Sea autumn spawners withdraw from the drift-net grounds in July and many of them are found on the Fladen ground and give a start to the herring trawl-fishery in late July. By the middle of September the majority of them have left these grounds in a movement southwards towards their spawning grounds in the middle or southern North Sea and the eastern entrance to the English Channel.

From the dispersal of those groups that do not belong to the Scottish autumn spawners from the drift-net grounds in July, it follows that landings during the earlier part of the summer herring fishery are no index of the landings during the later parts. A decline in the drift-net catches at the latter part of the season is inevitable if the spring spawners and southern North Sea late autumn spawners are numerous, and if the autumn spawning component is small, complete collapse of the fishery may result, as was strikingly illustrated in 1930.

The author's investigations constitute a new and valuable contribution to the understanding of the complicated composition of the herring shoals and their movements in the northern North Sea. The author remarks that he has made no attempt to link up any of the stocks with Norwegian herring, but it would have been of interest if the author had discussed the relation between the spring spawners in the northern North Sea and those spawning on the west coast of Norway.

Sven Runnström.

H. Lissner. "Zur Biologie der Makrele des Bosporus." Internat. Rev. d. ges. Hydrobiol. u. Hydrogr., Bd. 36, H. 1/2, S. 184—212, 10 Abb. Leipzig, 1937.

This is an interesting study of an important food fish, the biology of which is, even in west-European waters, still only partly understood, and any contribution to the knowledge of its biological and ecological conditions at the extreme south-eastern end of our continent should be welcomed.

The Scombridae in general, as is well known, are the principal food fishes in the Bosporus. According to statistics collected at Istanbul for a series of years the representative of the genus *Scomber* which is characteristic of the Mediterranean (*Sc. colias*) seems to be greatly outnumbered by the common mackerel with which the treatise under review is exclusively concerned.

The mackerel fishery of the Bosporus is carried out on a self-contained stock, distributed along the littoral regions of the Black Sea, and resorting for spawning purposes to a submarine current of high salinity and high

temperature (in winter), flowing out from the Sea of Marmara. This invasion of mackerel begins at the end of November, though the fishes have not yet reached maturity at this time. In early summer, after the spawning season, the mackerel shoals disperse towards the Black Sea again, to pacify their craving for food. So there are two fishing seasons in the Bosporus: one in the winter months (chiefly December—January) and another in the spring (chiefly April) on the emigrating spent fishes. According to the author's investigations and to the experience of the local fishermen, it seems that spawning mostly occurs in April and May, though neither eggs nor larvae have been found in the Sea of Marmara. Eggs have been recorded by other writers from the open Mediterranean; developing embryos are to be distinguished from those of Atlantic waters by a more extensive scattering of the characteristic moss-green pigment.

Race investigations (on fin rays and on the vertebral column) have been made by the author, and in regard to the last factor it may be stated that the number of vertebrae in fish from the Bosporus may be said to be remarkably constant, for in a large material of 936 mackerel no less than 98·3 % had 31 vertebrae (including the urostyle), which appears to be in accordance with statements of Ford who personally informed the author that in 150 mackerel from the western part of the English Channel he could not find a single departure from this same number. In the few cases in which the number is less than 31 the reduction seems nearly always to involve the last vertebra + urostyle, which coalesce into a single mass; if the number is more than 31 the additional vertebra is intercalated behind the 26th (which is the beginning of the "tail") in the complete series.

Similar examinations of herring skeletons by Ford have told us (and the present writer is able to confirm this) that in herring with 57 vertebrae the "tail" has on an average 0·3 of a vertebra *more* than in herring with 56 vertebrae. It would seem, then, that an additional vertebra as a rule affects the "tail", and no other part of the skeleton.

After giving some data about the food of the mackerel caught in the Bosporus the author proceeds to the problem of age and growth. As scales are unreliable and deciduous, otoliths have to be used for age determinations, and of course measurements of adult fishes were also useful. It turned out that these Turkish mackerel are slow growers. The length of spent fish varied between 18 and 22 cm., and larger ones, such as are quite common in the North Sea, were not found at all. On the other hand these larger North Sea mackerel appear to be older than might be expected: probably they are 5—10 years old.

The author gives a table, the data of which were provided by examination of the characteristic, strongly outwards-curved otoliths, from which one may learn that out of a material of 108 fishes the age of three years (at which first maturity is reached) gives an average length of 20·72 cm. and that in after years only very little is added to this length, so that a mackerel of five years is but 21·33 cm. long. It is, however, not unlikely that these data on age are minima, as these investigations of otoliths, taken from fish on the market, are not enlarged and controlled by continuous observations of these organs from the post-larvae onwards.

The paper concludes with desiderata regarding spawning places, behaviour of larvae and further race investigations on Mediterranean, Atlantic and American mackerel. The mackerel of the Black Sea and the Sea of Marmara are, as has been said, a wholly isolated and self-contained branch, and therefore further studies would be interesting, with a view to deciding

whether environmental factors may influence hereditary characters. It must be said that the fact of the same constant number of vertebrae in such widely different regions as the Bosporus and the western Channel is not in favour of the theory of moulding force provided by environment.

J. J. T.

F. Frade. "Recherches biométriques sur la maturité sexuelle du thon rouge"; "Recherches sur la maturité sexuelle du thon rouge de l'Atlantique et de la Méditerranée." Trav. Stat. Biol. Mar. de Lisbonne, No. 41, p. 2137—2142; No. 42, p. 243—250. Lisboa, 1936; 1938.

Ayant précédemment étudié la maturation des gonades chez le thon rouge génétique de l'Atlantique (*Thunnus thynnus* L.), le Dr. F r a d e a cherché à vérifier si la marche du phénomène était la même dans l'Océan et la Méditerranée.

La Station Océanographique de Salammbô, par l'envoi d'échantillons fixés provenant de poissons des madragues tunisiennes, permit à l'auteur une comparaison avec les exemplaires pris en Algarve au cours de la même saison de pêche.

Pour caractériser l'état de maturité sexuelle, F r a d e distingue 7 stades (A, B, C, · · · F, G.) qu'il définit par des indices numériques calculables d'après le poids relatif des gonades, et pour lesquels il indique l'aspect histologique correspondant.

Sur ces bases F r a d e a établi que, comparativement aux thons d'Atlantique, les thons des mers tunisiennes se montrent sexuellement moins avancés. C'est ainsi qu'au mois de juin, chez les deux sexes, en Atlantique, les stades A, B, C, D se trouvent représentés, A et B prédominant, tandis que dans les testicules examinés provenant de la Méditerranée, le stade B n'était pas dépassé.

L'auteur relève en outre une discordance chez les thons tunisiens. Les individus (♂ et ♀) pris fin juin à la thonaire de Sidi-Daoud se trouvent être au même stade de maturité que ceux pêchés au début du mois à la madrague de Cap-Zébib, c'est-à-dire manifestement en retard par rapport à ces derniers et également à ceux provenant de Monastir. F r a d e en tire cette intéressante déduction que "*des groupes à différents stades sexuels se déplacent indépendamment vers les lieux de ponte*".

"Si les renseignements concernant la maturité des glandes de quelques thons", conclut F r a d e, "représentaient en réalité l'état sexuel du moment de la capture des groupes auxquels ils appartiennent, on serait autorisé à admettre qu'il n'y a pas synchronisme de la maturité pour les divers groupes de thons qui fréquentent la Méditerranée et que, d'une année à l'autre, pour une même zone, un décalage de l'époque de fraie peut avoir lieu".

Toutefois — et l'auteur l'a déjà remarqué — on ne saurait se prononcer sur l'examen d'un petit nombre. Pour avoir une idée parfaite, des données plus nombreuses et se rapportant à diverses régions, sont nécessaires. Et ici apparaît la nécessité d'avoir une méthode d'appréciation uniforme, pratique et conduisant à des résultats comparables. Celle qui nous est proposée par F r a d e — et qui fait l'objet de la première des notes examinées — semble parfaitement convenir.

L'auteur y envisage de rapporter d'abord le poids des gonades au poids du corps; puis, pour des raisons de commodité des opérations, il remplace le poids du corps par celui de la tête (qui lui est proportionnel). Ayant enfin établi une concordance entre ce poids de la tête et la longueur du corps, il substitue, pour le calcul de l'indice, le second nombre au premier. Pour définir le point de maturité, deux opérations simples sont dès lors nécessaires:

une pesée (glandes génitales) et une mesure (longueur du corps). Point n'est besoin d'être grand clerc.

Les résultats ont déja confirmé la valeur de la méthode. Il est souhaitable que les chercheurs de tous pays l'adoptent, apportant ainsi une contribution utile à l'étude de la question de l'évolution sexuelle chez le thon, étroitement liée au problème important des migrations.

H. Heldt.

H. O. Bull. "Studies on Conditioned Responses in Fishes. Part VIII. Discrimination of Salinity Changes by Marine Teleosts." Dove Mar. Lab. Rep. for year ending 31st July 1937, pp. 19—35, 3 figs. Newcastle-upon-Tyne, 1938.

In this paper, number eight of a series of studies on the sense physiology of fishes, Dr. Bull investigates the ability of 30 individuals, belonging to 17 species of marine teleosts, to perceive small changes in the salinity of the water. It will be clear that such an ability may play an important role in determining their behaviour and is therefore of great importance for all fishery research. The work was carried out in a sound-proof room and with an apparatus that cannot well be described in a few lines (so that the reader must be referred for this to the original paper), but in which in an ingenious way all factors other than the salinity changes were excluded. The principle of the investigation, as in the former studies, was to train the fishes to seek for food as soon as a reduction of salinity was perceived. The salinity was first reduced by 4 $^0/_{00}$ (from 34 $^0/_{00}$ to 30 $^0/_{00}$); then the reduction was gradually diminished in order to find the limits of perception. As a general result we may summarize by saying that all individuals perceived reductions varying between 0·17 $^0/_{00}$ and 0·45 $^0/_{00}$ and so could discriminate between water of a salinity of 34 $^0/_{00}$ and of 33·83 $^0/_{00}$—33·55 $^0/_{00}$ respectively. Two-spotted gobies (*Gobius flavescens*) even went so far as to perceive a reduction of between 0·06 $^0/_{00}$ and 0·11 $^0/_{00}$. Among the species studied were five of economic importance (cod, whiting, coalfish, plaice, and flounder); all these could discriminate a change in salinity of 0·2 $^0/_{00}$.

J. A. Bierens de Haan.

C. M. Breder, Jr. "A contribution to the Life Histories of Atlantic Ocean Flyingfishes." Bull. Bingham Oceanogr. Collect., Vol. VI, Art. 5, 126 pp., 48 figs. New Haven, Conn., 1938.

In 1935 Dr. Anton F. Bruun published his valuable monograph on the flying-fishes (Exocoetidae) of the Atlantic, and no discourtesy is intended to the present contribution in referring to it as supplementary to that work. Actually, Dr. Breder had gathered together a considerable amount of material with a view to preparing a revision of the Atlantic flying-fishes, but the appearance of the Danish work rendered the publication of much of this unnecessary. The special value of the work under review lies in its detailed accounts of the young stages of a number of species, since these were scarcely considered by Dr. Bruun. There can be little doubt that much of the confusion formerly existing in the systematics of this interesting group of fishes was due to ignorance of the extraordinary ontogenetic changes undergone by some of the species, and Dr. Breder has done a really useful service in reducing chaos to something very near to final order. The excellent

drawings of both adults and young, mostly by Mr. Ralph Graeter, should prove invaluable to other workers in this field.

Some seventeen species and sub-species, grouped into eight genera, are dealt with in this paper. Where the matter has not been fully covered by Bruun, the characters of the adults are discussed, and the conclusions of the earlier author confirmed or criticized. Then the eggs and young forms are described in so far as these are known, and finally, in many cases, the distribution of the particular form is charted. The very remarkable mandibular barbels developed as a transitory phase in the young of certain genera, varying from a mere knob-like process to trailing streamers longer than the fish itself, are important features by means of which the young may be identified, but the author finds difficulty in accounting for the presence or absence of these ornaments in terms of function.

The main systematic part of the paper is followed by a shorter but equally important general part, which contains a thoughtful section on the phylogeny of the flying-fishes and their allies, as well as some new observations upon their habits and distribution. Dr. Breder is to be congratulated upon the completion of this contribution to the taxonomy of the group, and it is to be hoped that he will find time to extend his investigations to the species of other oceans.

J. R. Norman.

L. H. Matthews. "The Sperm Whale, *Physeter catodon*." Discovery Rep. Vol. XVII, pp. 93—168, figs. 1—67, plates III—XI. Cambridge, 1938.

"Notes on the Southern Right Whale, *Eubalaena australis*." Ibidem, pp. 169—182, plates XII—XVII.

"The Sei Whale, *Balaenoptera borealis*." Ibidem, pp. 183—390, figs. 1—113, plates XVIII—XIX.

The work of the Discovery investigations at whaling stations in South Georgia has embraced all species of whales brought in. In previous volumes of the *Discovery Reports* there are several papers on the fin and blue whale, and in the present volume Mr. Matthews has, in all, four papers on the humpback, sperm, right and sei whales. — The paper on the humpback was reviewed in an earlier number of this journal.

The material for the three papers now under review has been collected during the course of six seasons from 1925 to 1931 and it includes examinations of 81 sperm whales, 5 right whales and 220 sei whales In the case of the sperm and sei whales the author has also made use of the catch statistics available at the British Museum (Nat. Hist.).

The routine examination of whales by the Discovery staff consists of an entire series of standard measurements of the various parts of the bodies of the whales, and observations on colour, baleen (or teeth), food content, internal and external parasites, external and internal genitalia, and degree of physical maturity.

This material enables an account to be given of the external characters of the sperm whale and the sei whale, and their life histories. The number of right whales, however, is naturally too small to permit of similar treatment by the author.

1. The external characters of the sperm whale and their variation are shown in a series of graphs and tables, and the author concludes that, as far as this whale is concerned, no sub-division of species or geographical races is necessary.

The description of the appearance and colour of the sperm whale is supported by drawings and photographs.

A most interesting part of the paper is that which concerns the breeding and growth of the species, periods in the life history of the sperm whale which have hitherto been little known. In spite of the fact that the material is small the author has succeeded in drawing many conclusions. Tentative though he calls them, they seem convincing nevertheless.

The majority of matings take place during the period between August and December, although there seems to be no definite sexual season in the male. The period of gestation is calculated at about sixteen months and the length of the young at birth is about 4 m. Lactation lasts probably more than six months. From examination of the ovaries of 14 females it is concluded that breeding takes place once every two years. Sexual maturity is reached at an age of not more than two years in the case of the male and about 15 months in that of the female, at lengths of 11·5—12·5 m. and 9—9·5 m. respectively. Physical maturity is probably not reached before the age of 8—9 years.

The sperm whale feeds chiefly on cephalopods. Only a very few of the whales examined had empty stomachs. In the majority, both at South Georgia and South Africa, remains of cephalopods were found, mostly beaks and in some also fish remains. Remains of giant squids were rare but nearly all the males had scars caused by them. The author states that scars caused by suckers up to 10 cm. in diameter are common (in his table, however, I find no record of scars of more than 8 cm. in diameter).

The sperm whale belongs to tropical waters, but migrates towards temperate zones in the summer. A small proportion of the males migrates to higher latitudes during the summer season.

In modern whaling the sperm whale is an insignificant factor. The world catch probably does not exceed 2,000—2,500 sperm whales per annum. (Since this statement was made the "International Whaling Statistics for the season 1936—37" have been published, and these show that 7,048 sperm whales were killed during the season in question; 3,776 off the coast of Peru).

By virtue of the international agreement of 1937 sperm whales measuring less than 35 feet in length may no longer be captured, and this affords almost complete protection to the cows. In this connexion it is important to remember that the sperm whale is polygamous.

2. Mr. Matthews calls his paper on the right whale "Notes", and these notes are of real importance, although at present they do not make any contribution towards solving any of the many open questions connected with this interesting species of whale. Nor does the author adopt any attitude to the question of whether the southern right whale is identical with the Biscay whale. The greatest attention has been devoted to the bonnet and the other callosities. The author favours the view that the callosities are natural structures representing hair groups in other whales.

There is a short note on the behaviour of a right whale which the author had an opportunity of observing at close quarters in Undine Harbour, South Georgia, in 1925.

3. From the examination of the external characters and their variation it is concluded that the southern sei whale is identical with the northern species.

The paper contains the usual sections on body proportions, colour, hair, ventral grooves and baleen, accompanied by a number of tables and graphs.

The sei whale feeds on pelagic crustacea — in the Antarctic on the krill, *Euphausia superba*, off the coast of Africa possibly also on copepods, and off Patagonia on the pelagic post-larva of *Munida gregaria*.

Breeding and growth resemble those of the blue, fin, and humpback whales, as described in previous Discovery reports.

In the case of the southern sei whale the main part of the mating season is from May to August. The period of gestation is about twelve months and the young are born at a length of about 4·5 m. Lactation lasts about five months and the calf is weaned at a length of 8—9 m. It is concluded that this species breeds once every two years.

Sexual maturity is reached at the age of 18 months and at a length of 14·5 m. in the case of the female and 13·5 m. in that of the male. Physical maturity is attained at the age of 10—11 years.

Like blue and fin whales, the sei whale makes a feeding migration to higher latitudes during the summer season, and a breeding migration to tropical and sub-tropical waters in the winter.

South Georgian waters represent the approximate southern limit of the migrations and sei whales occur there in greatest abundance when the temperature of the sea is highest.

The economic importance of the sei whale in world whaling is at present small, but the author suggests that the interest of whalers in this species will increase in proportion with the decrease in the numbers of the more important blue and fin whales.

Johan T. Ruud.

P. Risting und **H. B. Paulsen: T. Iversen.** "Der Norwegische Walfang": "Der Norwegische Robbenfang". Handb. d. Seefisch. Nordeuropas. Herausg. v. H. Lübbert und E. Ehrenbaum. Bd. VIII, Heft 1b, S. 1—66, 85 Abb. S. 67—94, 44 Abb. E. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart, 1938.

In the first of these two papers the authors review in a general way the history and development of modern Norwegian whaling and give an account of the steps which the industry is taking at the present time to control and regulate, by international agreement, whaling activity as a whole in the Antarctic.

After an introductory section dealing with the sperm and right whale fishery carried on by American, English, Dutch and German whalers in the seventeenth, eighteenth and nineteenth centuries, the authors proceed to a consideration of the whales which are today commercially important — that is, the blue, fin and humpback, and to a lesser extent, the sei whale. A brief account is given of what is now known of the life histories and habits of these whales, together with tables showing the numbers and proportions in which these whales have been taken in the Antarctic in recent years. The main body of the paper follows, and is an abundantly illustrated and most readable historical account of the rise of Norwegian whaling in both hemispheres. It begins with the invention of the harpoon gun by Svend Foyn and with the construction in 1863 of the first whaler armed with harpoon guns, the "Spes et Fides". She carried seven guns from which four harpoons were fired at each whale. The history ends with the London International Whaling Conference of June 1937.

The whalers who established themselves in the 'eighties of the last century on the coast of Finnmark had much to contend with, for in addition to the

rapid diminution of their catches, which set in after a few years, there was also continual friction between the whalers and the fishing population, who believed that whaling was harmful to their trade. This resulted, in 1903, in the passing of a law forbidding whaling on the coast of Norway. The whalers then turned their attention to the west coast of Iceland and presently to the east coast. When in due course the catches declined in this area also they fished from the Faroes, the Shetlands, the Hebrides and the west coast of Ireland. The steadily diminishing catches in the northern hemisphere on all the grounds whither the whalers sent their ships, together with the bitter hostility of the fisherfolk everywhere (except in the Faroes), led the whalers at the beginning of the present century to turn their eyes southwards. Here was a vast, free and open ocean, unencompassed by land masses and already known since the voyage of W e d d e l l to be the home of great numbers of whales. From the time of the initial venture of Captain C. A. L a r s e n down to the present enormous development of modern pelagic whaling, with ships of 20—30,000 registered tons and a capacity of 200,000 barrels of whale oil, the story which the authors have to tell is a familiar one. They deal with the measures of control introduced in successive years and set forth in conclusion the twenty-two articles of the international whaling agreement reached in June 1937. Since then a second agreement has been signed in which further measures of control have been adopted. It gives hope for the future, not only so far as the whaling industry is concerned but in a wider sense, that it has been possible to arrive at these agreements. The Norwegians themselves have played a major part in bringing them about and to their wisdom and foresight the authors pay a well-deserved tribute.

The second paper in this volume is a review of the Norwegian sealing industry, as thoroughly readable and as excellently illustrated as the first.

The seals which are the main object of pursuit in the north are the Greenland seal (*Phoca groenlandica*) and the bladder-nose (*Cystophora cristata*). The walrus, ringed seal and blue seal are of very secondary importance. The Greenland and bladder-nose seals are hunted in the spring when they bring forth their young in the pack-ice of the White Sea, Spitsbergen and Franz Josef Land on the east (known to the sealers as the "East Ice"), and in that of the east coast of Greenland and the Denmark Strait on the west (known to the sealers as the "West Ice"). Both the young and old animals are taken as they lie on the floes; the young are clubbed with ice-axes and the adult or yearling animals, which can escape by swimming, are shot.

In a historical survey of the industry the author shows how the Norwegian sealers, using schooners with auxiliary engines, displaced those of other nationalities, mainly British, from the West Ice region. The Norwegian sealers came mainly from the province of Vestfold. From the beginning of the present century onwards, however, the sealing passed to a greater and greater extent into the hands of men from the province of Möre, who used small steam or motorships of about 250 registered tons. These small vessels had the advantage that, unlike the larger schooners, they could be employed in fishing on the Norwegian banks between the spring sealing seasons. Norwegian sealing is now carried on almost entirely by means of such ships as these.

In conclusion the author takes us on a sealing expedition to the White Sea and gives a vivid description of this hazardous and difficult trade and of the perils that arise from weather and ice conditions and also, not infrequently, from the stray bullets of neighbouring sealing parties.

F. D. O.

A. E. Hopkins. "Experimental Observations on Spawning, Larval Development and Setting in the Olympia Oyster, *Ostrea lurida*." Bull. Bur. Fish., Vol. XLVIII, pp. 439—503, 4 pl., 38 text-figs. Washington, 1937.

This paper gives an account of five years work on the biology of the Pacific oyster, *Ostrea lurida*. The investigation was carried on in the neighbourhood of Olympia, Washington, where the beds have been developed by a system of diking the flats at the head of the bays and inlets, whereby sufficient water is retained over the oysters at low tide to prevent losses by summer heat and by freezing. *Ostrea lurida* belongs to the viviparous group, being closely related to the European native, *O. edulis*, from which it differs chiefly in never reaching a size greater than two inches. On account of its small size it has never been of great commercial importance. Further, it has never been sufficiently abundant to reach markets all over the country, and production has declined during the last forty years, due principally to depletion of the natural beds. At the end of the last century, however, oyster growers in Puget Sound began to develop the system of diking the grounds, and it was found that by this means oysters could be cultivated on grounds which were formerly unsuitable. Today, practically all suitable ground in the inlets near Olympia, Washington, is diked, the dikes being made of concrete or, more recently, of creosoted lumber.

The temperature conditions in the dikes are peculiar, as during the few hours when the tide falls below the level of the dikes the temperature may either rise or fall rapidly under the influence of summer heat or winter frost, respectively, and, immediately the flood tide flows over the dikes, a very rapid rise or fall of temperature may occur. During the summer water temperatures as high as 25—30° C. are frequently experienced in the dikes, while during the winter the temperature may on occasion fall below 0° C.

Ostrea lurida like *O. edulis* is hermaphrodite and viviparous, but unlike *O. edulis*, all adult individuals may be expected to spawn as females during a normal season. Hopkins gives evidence which indicates that in exceptionally favourable seasons as much as 50 % of the stock may spawn twice as females, while in unfavourable years only 75 % may mature as females.

Spawning appears to begin when the minimum or high-tide temperature reaches 12·5—13·0°C., notwithstanding the occurrence for several days previously of low water (i.e., maximum) temperatures very much in excess of this figure. A marketable, i.e., 2-inch oyster, may be expected to produce a brood of 250,000—300,000 larvae. Development within the mantle cavity occupies 10 days, while the larval free-swimming period is estimated at about 30 days. This estimate may require revision when further investigations are made, as it is based principally upon the length of the larval period as observed in the laboratory, where development usually proceeds more slowly than under natural conditions. The estimated free-swimming period is about twice as long as in *O. edulis*. Abortion of early broods of embryos is shown to occur on occasion.

The setting season in Puget Sound is of several months duration, and consists of a number of distinct periods which in certain bays are remarkably uniform from year to year. The first period of the season is frequently followed by a second major setting period some 6 to 8 weeks later. The peak of a setting period usually coincides with the maximum range of a run of spring tides. There appears to be no lunar periodicity in the spawning of the stock such as has been stated to occur in *O. edulis*. The author suggests that the relation between the copper content of the water and

setting, as established by Prytherch for the American Atlantic oyster, may apply also in the case of *O. lurida,* although he does not give any direct evidence for this view, and is apparently not aware of the failure to repeat Prytherch's findings in experiments with larvae of *O. edulis.* Setting in *O. lurida* was found to be most intense at about 2 feet below the water surface and decreased continuously at greater depths. The greatest intensity of setting was found to occur on the undersides of horizontal surfaces, while the intensity of setting decreased as the angle of the surface to the horizontal increased. This has been vaguely recognized in the past as being true for most, if not all, cultivated species of oysters, but the investigations of Hopkins, some of which had been previously published, have placed these vague beliefs on a much surer foundation. A special type of artificial collector embodying the maximum amount of horizontal under-surface has been developed, and is much superior to the concrete coated egg-filler used on the Atlantic coast by Prytherch.

Following up the discovery that setting is most intense in the surface water layers, floats containing cultch have been used on a commercial scale to catch spat, enabling growers without good seed-catching ground to catch their own supplies of spat. The setting of spat was found to be most intense at about half tide, when the current was swiftest. This is in direct opposition to Prytherch's experience with larvae of *O. virginica,* which he found to set most frequently at the time of slack water, the larvae sinking to the bottom when the current exceeded about a half-foot per second. In the opinion of the reviewer it is unlikely that the behaviour of the larvae of two species of oysters should differ as widely as this and the need of further investigation of the relation between speed of current and the swimming behaviour and setting of the larvae of all cultivated species of oysters is clearly indicated. This problem, despite its practical importance, has as yet received no attention in Europe. This work of Hopkins may well serve as a model upon which further studies may be based.

H. A. C.

M. B. Schaefer. "Attachment of the Larvae of *Ostrea gigas,* the Japanese Oyster, to plane Surfaces." Ecology, Vol. 18, No. 4, pp. 523—527, 1 text-fig. 1937.

This work follows the same plan as the recent work of Hopkins on the setting behaviour of larvae of *Ostrea lurida.* It has been observed that under natural conditions the majority of the spat of *Ostrea gigas* set on the under-surface of shells. The experiments described in this paper were undertaken in order to ascertain whether the angle of surface influenced the intensity of setting, as had been shown to be the case in *O. lurida* by Hopkins. Large numbers of plates of clear glass were arranged so that they could be held at any desired angle over the beds of Japanese oysters in Puget Sound. Concrete coated cardboard egg-fillers were also used. The glass plates were put out on the beds for five days, and then removed, and the attached spat counted on all surfaces. Owing to the clearness of the waters in the region of Puget Sound selected, the influence of differential silting of the various surfaces was held to be negligible.

As with *Ostrea lurida* there is in *O. gigas* also a marked correlation between the angle of the surface to the horizontal and the amount of spat caught. Reckoning the horizontal under-surface as having an angle of 0° and the upper horizontal as 180°, and other surfaces accordingly, then the

frequency of setting falls off rapidly as the angle increases. The horizontal upper-surfaces caught very few spat, less than 2 % of the number caught on the same area of horizontal under-surface. If the intensity of setting is plotted against the angle of surface the points fall on a roughly hyperbolic curve. There is some evidence also for a belief that plates placed parallel to the tidal current catch more spat than those placed across the current. This is ascribed to the greater amount of larva-bearing water passing over the surface of plates placed parallel to the current. Further experiments with concrete coated egg-fillers confirmed the results obtained with the glass plates.

In addition to the suggestion advanced by Hopkins that results of this nature may be explained by the fact that the larval oysters swim with the foot uppermost and are therefore most likely to touch and cling to the undersides of horizontal surfaces, the author of the present paper suggests that the observed differences in the intensity of setting may also be due to the negative geotropism of the larvae of *Ostrea gigas*. Neither of these explanations is entirely convincing. The process of setting has been described in detail only in one species of oyster, *Ostrea virginica*, but it is well known that in this and other species of oysters the setting process occupies some time and is preceded by an explorative phase, during which the larvae crawl over the surface with the aid of the foot and appear to select a site for attachment. The interpretation of results such as those described above must be open to doubt until the actual setting process of the species concerned has been described.

H. A. C.

P. S. Galtsoff, W. A. Chipman, Jr., A. D. Hasler and **J. B. Engle.** "Preliminary Report on the Decline of the Oyster Industry of the York River, Va., and the Effects of Pulp-Mill Pollution on Oysters." U.S. Dept. Comm., Bur. Fish., Vol. II, Invest. Rep. No. 37, pp. 1—42, 27 figs. Washington, D.C., 1938.

An earlier investigation completed in 1931, which was mainly concerned with one of the inlets of Puget Sound, left no room for doubt as to the harmful effect on oysters of the sulphite waste liquor discharged from a large pulp mill situated on the shore of the inlet, in part of which *Ostrea lurida* is cultivated.

More recently the decline of the oyster fishery in the upper part of York River, Virginia, called for investigation, in view of an increasingly heavy mortality among the oysters (*O. virginica*) in that part of the inlet, accompanied by loss of flesh content, in particular glycogen, by thin shell formation and by reduced propagation. Recovery followed transplantation of affected oysters to other localities, thus indicating the absence of any cumulative effect, while a comparison of seasonal changes in physical and chemical conditions in the waters concerned, with those of an adjacent and similar inlet, revealed no abnormalities which could account for the poor condition of the oysters. The comprehensive field investigations which were made all pointed to pulp mill waste liquor as the cause of the decline of the oyster fishery.

Laboratory investigation of the effect of the effluent on shell movement, feeding and respiration were repeated and carried considerably further than in the earlier investigation, where, as a result of keeping oysters in various concentrations of the effluent in sea water, there had been noted an inhibition of new growth, an increase in the periods during which oysters

remained closed, a reduction in the rate of feeding, and in the higher concentrations a considerable mortality. The physiological effects in detail of effluents from the three main outlets have been compared in the present case, and investigation of the effect of fractions of the effluent and of pure compounds known to occur in pulp mill wastes are still in progress. Although no chemical means are available for detecting the presence of pulp mill effluent in the dilutions in which it occurs over the beds, the conclusion is inescapable from the field and laboratory investigations described in this report that the pulp mill effluent is responsible for the present condition of the oyster fishery.

H. P. S.

T. Gaarder. "Chemische Schwankungen der Auster in Norwegischen Brutpollen." Compt. rend. Lab. Carlsberg, Sér. chim., Vol. 22, pp. 173—181, 5 figs. Volume jubilaire en l'honneur du Professeur S. P. L. Sørensen. Copenhague, 1937.

This short paper comprises a preliminary account of an investigation on the seasonal variation in the chief classes of chemical constituents of European oysters (*Ostrea edulis*) during spring and summer in the Norwegian breeding pol or pool, Selvaagen. In April 1936, 930 five-year-old oysters were transferred from an open pool, Ytrepollen, to Selvaagen. In this breeding pool progressive mortality occurred until few individuals were left towards the end of the breeding season in September. The conditions in the pool contributing to the mortality are briefly discussed. Samples of oysters were taken at intervals from the open sea and breeding pools for analysis and comparison, but only those taken from the breeding pools are described in the paper. Estimates were made of water content, dry weight, protein, fat, carbohydrate, ash, C, P, S, Cu, Fe, Zn, Mg, Ca, K, Na, as well as Cl, F, Br, I, whilst glycogen was specially determined in fresh material. Flesh weight, shell weight, and sex-condition were also recorded.

Sex is recorded as changing from almost wholly female in May to almost wholly male in late summer, a relatively small proportion of hermaphrodites and larviparous females occurring from May to later summer. Average flesh weight, water content and dry weight all declined markedly after a slight rise at the end of May. The percentage protein and ash of the dry weight show an increase, while other categories of substances a decline, in the period under observation. On the other hand dry weight varies directly with water content; carbohydrate, fat and ash vary directly but at different rates with protein content; glycogen and carbohydrate vary together.

The percentage of iodine in the dry weight — unlike other constituents — does not increase, but attains a minimum in May, leading to the suggestion of a minimum concentration in the water from spring onwards.

A full account of this work will be awaited with interest, as the condition of oysters in these breeding pools, apart from the importance of variation with sex-condition, may be helpful in understanding the behaviour of stock material in those ponds and tanks which are used for experimental production of spat in other European countries.

J. H. Orton.

Current Bibliography.

Prepared by the Editor with the assistance of Miss Thursby-Pelham.

NOTE. The scope of the Bibliography is limited in the main to the area covered by the Council's activities, but there are included papers of general interest relating to other areas in North Temperate and Arctic regions and exceptionally elsewhere. Limnological references are not as a rule given, but papers relating to brackish waters and to salmon and freshwater fish studied by the Council are included.

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